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COARSE COAL IN WATER SLURRIES -
FULL SCALE PIPELINE TESTS

Prepared for Transportation Development Centre,
Transport Canada

by

R. Gillies
D.B. Haas
M.H. Small
W.H.W. Husband

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SASKATCHEWAN RESEARCH COUNCIL

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre.

PROJECT TEAM

The project team for the Saskatchewan Research Council was composed of:

R. Gillies
D. Haas
W. Husband
J. Lychak
D. McEwan
R. McKnight
B. Pizzey
P. Shergevitch
M. Small
J. Wright

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17 Abstract

A study was conducted by the Saskatchewan Research Council to investigate the pumping of coarse particles of metallurgical and thermal coals in water. The results of tests in pipelines of 50, 100, 150, 250 and 500 mm in diameter are reported. The study showed that it is technically feasible to pipeline coal containing particles as large as 50 mm at concentrations in the 50 to 60% by weight range. Methods to correlate the hydraulic data are presented in the report.

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17. Résumé

Ce rapport rend compte des travaux menés par la Saskatchewan Research Council sur le transport hydraulique des charbons destinés aux centrales thermiques et métallurgiques, dans des canalisations de 50, 100, 150, 250 et 500 mm de diamètre. L'étude a montré qu'il est techniquement possible de transporter par pipe-line du charbon, à une concentration massique comprise entre 50 et 60 pour cent, la dimension des plus gros fragments pouvant atteindre 50 mm. En outre, le rapport traite des méthodes utilisées pour corréler les données sur l'aspect hydraulique des expérimentations faites.

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Judy Creek coal samples were prepared by the Western Regional Laboratory of EM & R in Edmonton. Fording Coal of Elkford, B.C., Kaiser Resources of Sparwood, B.C., and Luscar Sterco Limited of Edson, Alberta also supplied coal samples for the study.

SUMMARY

On January 1, 1980 the Saskatchewan Research Council (SRC) was awarded a contract by the Department of Supply and Service (DSS) on behalf of the Transportation Development Centre (TDC) to investigate the pumping of coarse particles of metallurgical and thermal coals as slurries in pipelines of 50 to 500 mm in diameter. One purpose of the investigation was to assess the technical feasibility of moving run-of-mine coal from remote minesites to preparation plants 10 to 100 km away by using pipelines. Another purpose was to generate hydraulic data which could be used to check and improve mathmatical models and correlations. A third purpose was to demonstrate how the data could be used by people faced with the problem of assessing the potential of pipelines for moving coal from mine to preparation plant.

The experimental program was completed during March, 1982. The tests showed that coal particles up to 50 mm in diameter could be pipelined at concentrations in the 50 to 60% by weight range in 150, 250 and 500 mm diameter SRC pipeline loops. It was found that the coal slurries could be bedded out during shut-down exercises and then picked up again on start-up several hours later. The feasibility of pumping coal particles larger than 50 mm was not investigated.

Pressure gradients due to flow for the coarse coal slurries were higher than those for conventional fine grind (14 mesh top size) coal slurries. However, the pressure gradients were not so high as to rule out the possibility of short distance coarse coal pipelines.

The results of the tests are summarized in this report. In

addition to pressure gradient data, solids concentration profiles and particle size degradation rate measurements are included. A sample calculation showing how the data may be used for pipeline design has been included.

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1. INTRODUCTION

More than 90% of Canada's coal reserves are located in western Canada. This coal has become a vital part of the country's energy picture. Its importance will continue to grow as domestic reserves of oil and gas decline, oil imports increase, and world prices for oil and gas increase.

World demand for coal is steadily increasing. It is expected that the export of western Canadian coal will increase significantly over the next few years. This will be necessary to offset the adverse balance of payments resulting from the import of increasing quantities of crude oil.

Most of the Canadian coal reserves tagged for export are located in the mountainous regions of British Columbia and Alberta. Transportation of the coal to seaports is a major problem. Railway arteries to the West Coast are already operating near capacity. Increasing the capacity of the railways through the mountains is extremely costly. Another problem is that the majority of the coal reserves are far from existing railways. The construction of spur lines to the proposed minesites is made difficult by the rugged terrain.

An efficient transportation system would include a central preparation plant for coal from several minesites. The preparation plant would be located near an existing community. A revamped railroad system could be used to transport the coal from the preparation plant to the coast. An alternative would be to build long distance slurry pipelines. The coal for a long distance pipeline would have to be ground fine to reduce energy consumption. Positive displacement pumps would be used since their efficiencies are higher than those for centrifugal pumps. A dewatering plant would be required at the port.

An efficient collection system for moving coal from mine mouths to preparation plant would use coarse coal slurry pipelines. Since the distances would be relatively short, coal with a top size of 50 mm could be moved using centrifugal pumps. The penalties due to higher pressure gradients for coarse solids and the low efficiencies of centrifugal pumps would be offset by the low capital costs of coarse coal slurry pipelines and by the economy of scale from using a central preparation plant. Pipelining would minimize environmental effects, would be independent of weather and would be least affected by escalation of labour costs.

Existing coal pipelines in other parts of the world pump slurries of fine particle size, i.e. less than 14 mesh (1.2 mm), to minimize operating problems and energy requirements. Preliminary work at the Saskatchewan Research Council has shown that such a fine particle size is not essential for a mine-mouth to preparation plant pipeline and that a coarse slurry with a maximum particle size of 50 mm can indeed be considered practical. The purpose of this study was to confirm the preliminary work and to expand on it by measuring the effects of particle size, particle size distribution and concentration of coal in the slurry upon energy requirements. The results would then be useful to engineers, designers and planners faced with assessing the advantages of mine to preparation plant pipelines in the overall transportation system for moving coal from mine to seaport.

Experience at the Saskatoon pipeline centre has shown that coals from different fields perform differently in pipelines. Therefore it was decided that coals from four fields be selected for pipeline tests. Two metallurgical and two thermal coals were selected. The coals were tested in pipelines from 50 to 500 mm in diameter. Engineering correlations were made to condense the headloss data. A modified version of the sliding bed model of Wilson was assessed as an instrument for predicting headlosses. Particle degradation rates were measured and were fitted to the model of Austin and Luckie for comminution processes. A sample calculation has been included in this report to demonstrate how the data and correlations in this report would be used to aid in the design of a slurry pipeline.

2. PREVIOUS WORK

With renewed interest in coal as a fuel, there is a need for reliable methods to predict the performance of pipelines used in transporting coal and colliery waste. This material is usually much coarser than that used in long-distance coal pipelining, with profoundly different hydraulic behaviour. Although some pilot plant experience with injecting devices (1, 2, 3) or mine operation (4) have been reported, there have been few systematic experimental studies for coal slurries. A major difficulty in this sort of research is the necessity to work with industrial scale equipment to obtain credible results with particles of the actual size encountered in practice. It is thus necessary to handle substantial quantities of solid material.

A notable early study (5) at the U.S. Bureau of Mines using Pittsburgh Seam coal presented headlosses and documented a number of operating difficulties. An important early study of particle degradation was also made. Degradation is important hydraulically because the fine particles affect the viscosity of the carrier medium. It is also of considerable economic importance since it affects the design of separation systems.

Although extensive experience in handling fine-particle slurries, including coal (6), had been obtained in this laboratory with large pipelines, the first coarse coal experiments used lignite in 50 and 100 mm pipes (7). In this first study, headlosses obtained with slurries containing differing amounts of -44 μm material were found to be correlated reasonably well in terms of the Modified Froude number

$$\psi^{-1} = V^2\sqrt{C_{Dm}}/gD(S_s-1) \qquad (1)$$

The mean drag coefficient was obtained from the weighting

$$1/\sqrt{C_{Dm}} = \Sigma\, w_i/\sqrt{C_{Di}} \qquad (2)$$

Although the correlation is essentially empirical, it was particularly useful for friable materials such as lignite whose well-known degradation had precluded correlation of headlosses in earlier studies.

Subsequent investigations using other coals in 100 mm (8) and 150 and 250 mm pipelines (9, 10) required significant modifications to the test pipelines which had been originally constructed for use with fine-particle slurries. These test pipelines contained vertical sections to facilitate sample removal for particle size determinations. As the pipe diameter increased, fluctuations in headlosses became more severe and these eventually necessitated installation of new instrumentation and a computer system to process the data. These fluctuations were probably of the type reported by Pipelin, Weintraub, Orning and led to further major changes in the test circuit for the 150 and 250 mm pipelines for the present series of experiments. These considerations also affected the design of the 500 mm pipeline test loop.

The studies reported in reference 6 concerned two western Canadian coals of different density, size distribution and coefficient of kinematic friction for sliding on a glass surface. To extend the range of variables, the present investigations used three more coals and the additional large pipeline.

Since only cleaned coal had been studied to date, the tests were also designed to give a comparison of the behaviour of raw and cleaned coal. As an additional contribution to understanding of particle degradation, rates were to be determined in the 150 and 500 mm pipeline systems operating under identical conditions. Previous studies of lignite degradation in a 50 mm diameter test loop (11) and lignite and three other coals in a 100 mm diameter system (12) had established that degradation rates could be modelled satisfactorily with the conventional theory of comminution processes.

The headloss data reported in references 8 and 9 were found to be correlated reasonably well for any one coal in terms of ψ^{-1} and the dimensionless excess headloss ϕ_t defined by:

$$\phi_t = (i - i_f)/C_{vt}\, i_f \tag{3}$$

To interpret the difference in behaviour between the coals, the two layer model of Wilson (13) was used. In this model, shown schematically in Figure 1, the particles which are supported by fluid lift forces are assumed to be uniformly distributed over the cross-section with volumetric concentration C_1. The remaining particles have immersed weights which are transmitted to the pipe wall where a Coulombic friction process acts in parallel with the fluid friction. In the original version of this model (used in reference 10), the lower layer concentration is assumed to be constant at C_2, shown as (a) in Figure 1. The value of C_2 cannot be predicted in the present state of knowledge.

The total solids content is considered to be divided between suspended and contact load portions by Wilson's semitheoretical expression for C_c. In generalized form this is

$$C_c A = \int_{A_2} (c_t - c_1)\, dA$$

$$C_c = \Sigma C_{ci} \tag{4}$$

$$C_{ci} = 0.36\, (W_i/u_*)^2 \exp\, (90\, di/D)\; C_{ti}$$

The model consists of mass balance relationships:

$$C_{vt} = C_1 + C_c$$

$$AV = A_1 V_1 + A_2 V_2$$

and the momentum balance expressions for the two layers

$$0 = i\rho_f g - (\tau_1 S_1 + \tau_{12} S_{12})/A_1$$

$$0 = i\rho_f g + (\tau_{12} S_{12} - \tau_2 S_2)/A_2$$

The stresses at surfaces S_1 and S_{12} are predicted using expressions appropriate for fluids. τ_2 contains both fluid-wall friction and Coulombic sliding friction effects resulting from stress transmission between particles and the immersed weight of the particles. The normal stress at the wall due to the immersed weight of the particles at a distance y above the bottom of the pipe is then

$$(\rho_s - \rho_f)g = \int_y^{y_1} (c_t - c_1)dy$$

When multiplied by the coefficient of kinematic friction η_s, this gives the local contribution to τ_2 resulting from particle weight.

When the set of equations is solved simultaneously using specified values of η_s and the concentration distribution C(y), the model predicts V_1, V_2, i and the location of the interface between the layers.

The earlier study with $C = C_2$ in the lower layer showed good agreement of predicted and observed headlosses at high values of C_{vt} and low velocities. Agreement in this region is desirable since this region is of greatest practical interest. The η_s values which gave this agreement were similar to limiting coefficients of static friction for the coal particles sliding in a glass tube.

At lower concentrations, the agreement between predicted and observed headlosses was less satisfactory. There are at least two possible explanations for this: failure of the set of equations (4) to apply or alternatively, concentration profiles significantly different from those shown as (a) in Figure 1. To examine these possibilities, a gamma ray absorption system was used in the present investigation to determine chord-average values of solids concentration.

3. WORK STATEMENT

3.1 Original Work Program

The following program of work was agreed to under the terms of the contract.

1.0 Overall Objectives

To ensure that full advantage is taken of the potential for energy conservation through the use of the solid pipelining mode, where appropriate, in the national transportation system.

2.0 Project Objective

To provide hydraulic data on the movement of various slurries of thermal and metallurgical coal in a full scale (500 mm) pipeline, and to correlate these data with predictions previously made through extrapolation of laboratory scale tests.

3.0 Scope

The range of pipe diameters will include increments from 50 to 500 mm. The coal grades to be tested will include two western thermal and two metallurgical, particle sizes from -14 mesh to -50 mm.

4.0 Description of Work

The work, contracted to the Saskatchewan Research Council, will be performed in Saskatoon, with the monitoring assistance of the Western Research Laboratory of E.M. and R., and will include the following elements:

4.1 Thermal Coals

a) Judy Creek Coal

- Procurement of 110 tons of -50 mm coal
- Trucking of 80 tons of -50 mm coal in drums to the Saskatchewan Research Council (SRC) pilot plant - Saskatoon
- Trucking of 30 tons of -50 mm coal to the Western Research Lab (WRL) for crushing to 9.5 mm and washing
- Washed coal (10 tons) and raw crushed (-9.5 mm) shipped in drums to SRC (total 25 tons)
- Grinding 40 tons of the -50 mm at SRC to 14" mesh
- Hydraulic tests with -14" mesh coal in 50, 150, 250, and 500 mm pipeline loops
- Hydraulic tests with -50 mm coal in 150, 250, and 500 mm pipeline loops
- Hydraulic tests with -9.5 mm washed and raw coal in 100 and 150 mm pipeline loops

b) Century or Sheerness Coal

The work will be the same as with Judy Creek Coal.

4.2 Metallurgical Coals

a) Kaiser Resources clean Met. Coal

- Procurement of 41.5 tons of -50 mm coal
- Trucking of 40 tons of -50 mm coal in drums to SRC - Saskatoon
- Split of 1.5 tons shipped to Edmonton for carbonization tests at WRL
- Hydraulic tests in 150, 250, and 500 mm pipeline test loops
- After testing, a split of 1.5 tons from each of the 250 and 500 mm pipeline loops will be shipped to Edmonton for carbonization tests at WRL

b) Fording or McIntyre clean metallurgical coal

The work will be the same as with Kaiser coal.

4.3 Engineering Correlations

Design equations will be developed, for each coal tested, to permit accurate design of pipelines up to 500 mm in diameter.

4.4 Feasibility of Thermal Coal Line to Heavy Oil Field

The technical and economic feasibility of supplying coal via a pipeline to steam raising plants within a heavy oil field will be evaluated. The annual quantity of coal required, the size of the pipeline needed and the capital and operating costs of the pipeline will be determined.

3.2 Deviations from Original Program

Due to a shortage of Judy Creek coal (only 55 tons were received at SRC) element 4.1 a) was modified. The runs with -14 mesh Judy Creek coal in the 150, 250, and 500 mm pipelines were eliminated. In place of this cutback, runs were made with -8 mesh washed Judy Creek coal in the 50 and 100 mm pipelines and with -9.5 mm + 8 mesh raw Judy Creek coal in the 100 and 150 mm pipelines.

With the approval of the steering committee for the project it was decided that Coal Valley coal would be selected for the work in Element 4.1 b) instead of Century or Sheerness coals. A run of mine coal from the Mynheer B seam was chosen. The coal was crushed to pass 50 mm before performing the tests. It was decided that only one series of runs would be performed with the Coal Valley coal (-50 mm coal in the 250 mm pipeline loop). This was necessary to keep the cost of the project within limits.

Element 4.4 was modified at the suggestion of the steering committee for the project. Instead of a technical and economic feasibility study for a particular situation, a calculation was made to demonstrate how mathematical models and correlations could be used to aid in the design of a pipeline.

After testing the metallurgical coals in the 250 and 500 mm diameter pipelines, samples of the coals were sent to the Energy, Mines and Resources Western Regional Laboratory in Edmonton for coking quality assessments. It was found that the coking quality of the samples taken after pipelining was poorer than that of the samples which were not pipelined. It was decided that a new sample of the Fording coal would be obtained and that new samples of fresh and pipelined coals would be sent to EM & R for coking quality testing. During the original tests, care had not been taken to avoid the loss of fine material during sampling. During the repeated test, sampling was performed under stringent conditions and care was taken to obtain a sample that was representative of the bulk of the coal in the pipeline loop. The results of the repeated coking quality tests showed that, in general, there was a slight increase in the coking quality of the pipelined coal over the coal which had not been pipelined. The results of the coking quality tests are given in Appendix D.

4. EXPERIMENTAL

4.1 50 mm pipeline

The 50 mm test loop is shown in Figure 2. The pipeline was operated in the open loop mode. The slurry was fed from the holding tank to a 3 x 2 centrifugal pump powered by a 10 hp electric motor through a variable speed drive. The discharge from the pipeline was returned overhead into the holding tank. Velocities and solids concentrations were determined by diverting the total pipeline flow into a weighing tank for a measured period of time. Full discharge samples were also taken for particle size distribution determinations. A manometer was used to measure pressure drops over a straight section of epoxy lined pipe with a 52.6 mm inside diameter.

Ethylene glycol heat exchangers were used in all pipelines to maintain the pipeline temperature constant during the prolonged periods of pumping which comprised the tests.

4.2 100 mm pipeline

The 100 mm test loop is shown in Figure 3. The pipeline was operated in the closed loop mode. The slurry was fed from a holding tank into a 3 x 2 Wilkinson rubber-lined centrifugal pump. The slurry was returned to the tank through a downcomer pipe to a position just above the bottom of the tank. It was necessary to operate with a low slurry level in the tank to prevent short-circuiting of the larger solid particles through the slurry sitting in the tank.

A magnetic flux flowmeter was used to measure the slurry velocity.

Full discharge samples were obtained to calibrate the flowmeter. Full discharge samples were also obtained for particle size distribution determinations.

A manometer was used to measure pressure drops over an epoxy lined straight test section.

Solids concentrations were determined from the weight of coal added to the system and the density of the coal as determined from a sample taken during loading.

4.3 150 and 250 mm pipelines

Figure 4 shows the test loops used in the present investigation. The pipelines were operated in the closed loop mode so that the feed tanks were bypassed and the flow was returned to the pump inlet, allowing the feed tank to be used as a standpipe. The liquid level in the standpipe was only about 1 m above the axis of the pump inlet. A 12 x 10 Wilkinson rubber lined centrifugal pump driven by a 250 hp electric motor through a fluid drive was used for both the 150 and 250 mm pipelines. Flowrates were measured with a magnetic flux flowmeter located just downstream of the pump. This flowmeter had been found to perform satisfactorily in numerous earlier studies using fine-particle slurries when velocities could be verified by volumetric sampling. A standard orifice plate was used to check the magnetic flowmeter in water runs before and after the series of experiments reported here.

Pressure drops were measured with Viatran model 218 pressure transducers monitored by a Neff/Hewlett Packard system to gather and analyze pressure drops and velocities. These were recorded 750 times during a 45 second scan period.

In situ solids concentrations were determined from the amount of coal added to the system and the density of the coal as determined from a sample taken during loading. A major modification to the test circuit from that used in the previous study was the removal of the vertical sections. This was done because it was suspected that axial inhomogeneity developed in the slurries when the pipelines were operated for long periods at low velocities. These inhomogeneities could be a cause of the fluctuations mentioned earlier.

Since the pipelines were to be converted to a near-horizontal mode of operation, a means of sampling the flow had to be devised. A retractable centre-stream sampling device was constructed and tested by comparing the size distributions of its samples with those obtained by diverting the full flow. It was found that the sampler (Figure 5), constructed from 100 mm pipe, worked very well. The pipelines were originally epoxy lined but prolonged usage had eroded the epoxy coating in the lower half of the pipe to expose the steel wall.

4.4 500 mm pipeline

This pipeline is shown schematically in Figure 6. It was also operated in the closed loop mode. A 16 x 16 Allan-Sherman-Hoff centrifugal pump, driven by a 300 hp motor and fluid drive, was used to circulate the mixture. Velocities were measured with a 450 mm magnetic flowmeter calibrated with water against a standard orifice plate. The same methods were used for pressure drop, particle sizes and concentration determinations as for the 150 and 250 mm pipelines. Temperature control was also used. This pipeline was epoxy coated internally.

4.5 Gamma ray absorption

A schematic drawing of the gamma ray density meter is shown in Figure 7. A 100 millicurie Cs-137 source located in a lead block containing collimating slots was used to produce a planar horizontal beam of gamma rays. This could be moved to any position above the bottom of the pipe by a stepping motor system. Simultaneously, a tandem stepping motor moved a block containing the scintillating crystal and photomultiplier tube of the Ortec detecting system so that the source and detector were always aligned. Preliminary calibration tests were necessary to check pipe wall thickness and path length effects with water in the pipeline.

The results of the concentration profile measurements are given in Tables 1 to 10. The gamma ray absorption coefficient, μ_s, for a material may be determined from the expression $\ln (I_0/I) = \mu_s$

where I_0 is the gamma ray count through air,

I is the gamma ray count through one centimeter of the material.

Absorption coefficients were determined from small (less than 1 kg) samples of coal, but these were not considered to be very reliable for coal whose composition is variable. Since it is the difference between the absorption coefficients for the fluid and the coal which affects the computed solids concentration, and since the coal coefficients are fairly close to those of water, more reliable values of coal absorption coefficients could be obtained from tests using known high values of C_{vt}. These absorption coefficients varied with coal density in the expected manner. Small variations from run to run were probably due to the effect of gas retained on the coal particles. Variation in particle densities in the coal samples and the tendency of the higher density particles to travel in the lower portion of the pipe resulted in high apparent concentrations near the bottom of the pipe.

4.6 Procedure

Coal was received in 45 gallon drums or in bulk via flatbed truck. Moisture contents were determined from the density samples taken during loading. A typical series of tests involved velocity and headloss measurements at four concentrations. Samples for particle size determination were taken immediately after loading coal into the pipeline and after a series of headloss measurements at a given concentration. Data were always taken in the order from highest to lowest velocity. The lowest velocity usually corresponded to that at which a stable stationary deposit was present in the pipeline. This was determined visually. The advantage of this procedure is that the measured size distributions apply best to the important low velocity results in cases when the size distributions are changing rapidly because of degradation. Because of degradation and the length of time required to complete a traverse with the gamma ray system, the number of traverses was limited to those required to examine the simplifications of the two-layer model.

Degradation tests were conducted under nearly identical conditions in the 150 mm and 500 mm pipelines to determine the importance of equipment size in the degradation process. The tests used the same pump rotational speeds (330 ± 10 rpm) and the same concentration (53% by weight) of Kaiser coal. Continuous recirculation for 8 hours with periodic sampling for particle size distribution was used in these tests. Velocities were 2.95 m/s in the 150 mm pipeline and 3.05 m/s in the 500 mm system.

Eight hour attrition runs were also made for Judy Creek and Fording coal in the 150 mm pipeline. The pump speed was set at 330 ± 10 rpm for both tests.

It was found that the Coal Valley coal attrited considerably during the headloss determinations. Since concentration was built up by adding coal to material in the pipeline from the previous test, as the concentrations increased the average residence time of the coal also increased. After the completion of the test at the highest concentration, the pipeline was emptied, cleaned, and a fresh charge of coal was added to give the highest concentration again. A headloss test was performed using the fresh coal at this concentration.

5. RESULTS

5.1 Headlosses - empirical correlations

The experimental data are presented in graphical form in Figures 8 to 57 and in tabular form in Appendix A.

The results of empirical correlations performed on the data are presented as plots of ϕ_t vs ψ^{-1} in Figures 58 to 82 and in tabular form in Appendix B.

The water saturated coal density was used to determine C_{vt}. It was assumed that the coal as received was saturated with water but contained no additional (external) moisture that would contribute to the volume fraction of the carrier phase.

For the coarse coals (50 mm top size), any one set of measurements (a given coal, pipe and solids concentration) plotted in the form of ϕ_t vs ψ^{-1} gives a line with a slope near -1. However, displacement of the results between runs gives an overall slope of a regression line through all the data which is somewhat closer to the original Durand-Condolios value of -1.5. It should be noted that the customary dependent variable is ϕ (which uses discharge concentration rather than in-situ concentration).

The drag coefficients used in these values of ψ^{-1} were obtained from a correlation of experimental values reported in Reference 9. This correlation has been found to be applicable to all the western Canadian coals tested in this laboratory since 1972.

Like the results reported in Reference 10, slopes near -1 for the majority of the coarse-particle tests are consistent with Newitt's equation (a precursor of Wilson's two-layer model). Interpretation of the

ϕ vs ψ^{-1} results requires the model, however, since it is evident that there may be consistent differences due to coal properties and perhaps pipe size and slurry concentration.

The dimensionless groups are very useful for showing the effect of changing particle size distributions. Figures 73 and 82 show the headloss data obtained before and after the attrition tests of Figures 30 and 56. For the larger pipe, there is no change of any consequence. However for the smaller pipe there is a definite shift towards the pseudohomogeneous condition ϕ_t = constant as a result of degradation. The increased fines content is consistent with this behaviour.

In a similar sense, the effect of cleaning the coal can be shown conveniently in terms of the dimensionless groups. These results for tests in the 100 mm loop are shown in Figures 62 and 63. The results for tests in the 150 mm loop are shown in Figures 65 and 66. There was little difference between the raw and cleaned Judy Creek coals in terms of their hydraulic behaviour.

The Coal Valley coal contained the greatest percentage of coarse material of the four coals tested. There were large cyclical fluctuations in velocity and headloss. The period of the fluctuations corresponded to the time required for the slurry to travel around the loop once. Axial variations in solids concentration or particle size could have caused the fluctuations.

Possibly a variation in concentration and/or particle size occurred during loading of the loop. The coarse particles broke down quickly during recirculation. A method of addition was used to obtain higher coal concentrations for the tests of Figure 42. At the completion of data gathering for a test at a low concentration, fresh material was added to the attrited coal in the pipeline loop. As a result, the particle size changed significantly from one concentration to the next. The effects of particle size reduction were greater than predicted by the dimensionless groups (Figure 75). The effect of attrition during a normal series of runs is shown in Figure 43. The headlosses for a normal series of tests using the method of addition are compared to the headlosses using a fresh charge of coal in Figure 44. Again the dimensionless groups did not fully account for the differences in headlosses (Figure 76).

5.2 The Two-Layer Model - gamma ray absorption results.

In view of the systematic displacement of the ϕ_t vs ψ^{-1} curves, it was considered necessary to try to use the model to predict all the experimental results. This proved to be a stronger challenge to the model than the previous study of reference 10 for the following reasons:

1) A wider range of coal densities was used in the present investigation.
2) Since experimental measurements were available for the selection of the contact-load concentration distribution, the model had to be tested for both high and low concentration runs.
3) The range of pipe diameters was markedly increased by including the 500 mm pipe.
4) Slurry viscosity effects appeared to be important. In the previous investigation, the slurry viscosity was estimated from an expression which had been found to represent the results of

Couette and tube viscometer studies conducted in this laboratory with particles of fairly narrow size distribution. This expression was:

$$(\mu_1/\mu_f) = \exp[C_1/(0.2692 - 0.2254\ C_1)] \qquad (6)$$

To provide a fair test of the model, it is necessary to select or predict C_2, the coefficient of kinematic friction, and the viscosity-concentration function. Since the set of equations (4) had proved to be acceptable in the earlier study, no adjustment in this aspect of the model was considered to be justified.

It will be seen that a major modification of the model arose when the gamma ray measurements of solids concentration were examined. Instead of a constant-concentration lower layer, there was always a near-linear variation of the type shown as (b) in Figure 1. Distributions of this kind have been reported previously (15) in coarse-particle systems.

The model was then tested by considering low concentration (C_{vt} approximately 25%) and high concentration (45%) results for three coals in the 150, 250 and 500 mm pipelines. C_2 was taken as 0.50 for the low concentration and 0.75 for the high concentration in all cases. Values of η_s and the viscosity-concentration function were selected for the coals as compromises which represented all the velocities in the three largest pipelines at these two concentrations. The process of selection was essentially iterative and although one cannot claim to have selected a unique set of coefficients, the model has been subjected to a more severe test than in any previous investigation.

In the interest of brevity, only a small fraction of the data which was analyzed will be presented. Representative situations are chosen to allow some generalized conclusions to be drawn.

	Velocity = 1.40 m/s Solids Coefficient = 0.110		Velocity = 1.98 m/s Solids Coefficient = 0.123	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.059	0.1013	0.495	0.1032	0.494
0.159	0.1010	0.487	0.1018	0.458
0.259	0.0983	0.410	0.1009	0.435
0.359	0.1000	0.459	0.1013	0.445
0.459	0.0987	0.422	0.1000	0.412
0.559	0.0967	0.365	0.0986	0.376
0.659	0.0948	0.311	0.0963	0.317
0.759	0.0961	0.219	0.0967	0.327
0.859	0.0950	0.316	0.0944	0.269
0.959	0.0893	0.154	0.0944	0.269

Table 1

Gamma Ray Gauge Concentration Profile Measurements

-8 Mesh Washed Judy Creek Coal in Water

158.5 mm I.D. Closed Loop Pipeline

June, 1980

Mean Solids Volume Fraction = 0.385

Gamma Ray Absorption Coefficient for Fluid = 0.0839

	Velocity = 1.68 m/s Solids Coefficient = 0.120		Velocity = 2.29 m/s Solids Coefficient = 0.122	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.059	0.1140	0.834	0.1107	0.703
0.159	0.1112	0.756	0.1123	0.745
0.259	0.1071	0.643	0.1056	0.570
0.359	0.1041	0.560	0.1054	0.564
0.459	0.0997	0.438	0.1009	0.446
0.559	0.0980	0.391	0.0994	0.407
0.659	0.0963	0.343	0.0962	0.323
0.759	0.0950	0.307	0.0965	0.331
0.859	0.0898	0.163	0.0934	0.249
0.959	0.0858	0.053	0.0904	0.171

Table 2

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Raw Judy Creek Coal in Water

158.5 mm I.D. Closed Loop Pipeline

Start of Attrition Run, June, 1980

Mean Solids Volume Fraction = 0.450

Gamma Ray Absorption Coefficient for Fluid = 0.0839

	Velocity = 1.68 m/s		Velocity = 2.29 m/s	
	Solids Coefficient = 0.120		Solids Coefficient = 0.122	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.059	0.1102	0.729	0.1112	0.681
0.159	0.1095	0.709	0.1098	0.646
0.259	0.1035	0.543	0.1075	0.589
0.359	0.1012	0.479	0.1022	0.456
0.459	0.1018	0.496	0.1023	0.459
0.559	0.0986	0.407	0.0999	0.399
0.659	0.0966	0.352	0.0980	0.352
0.759	0.0953	0.316	0.0996	0.392
0.859	0.0957	0.327	0.0952	0.282
0.959	0.0925	0.238	0.0941	0.254

Table 3

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Raw Judy Creek Coal in Water

158.5 mm I.D. Closed Loop Pipeline

End of Attrition Run, June, 1980

Mean Solids Volume Fraction = 0.450

Gamma Ray Absorption Coefficient for Fluid = 0.0839

	Velocity = 1.75 m/s		Velocity = 2.27 m/s	
	Solids Coefficient = 0.1035		Solids Coefficient = 0.0995	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.059	0.1005	0.847	0.0972	0.853
0.159	0.0984	0.740	0.0946	0.686
0.259	0.0965	0.643	0.0933	0.603
0.359	0.0938	0.505	0.0921	0.526
0.459	0.0932	0.474	0.0911	0.462
0.559	0.0895	0.286	0.0886	0.301
0.659	0.0907	0.347	0.0882	0.276
0.759	0.0883	0.224	0.0892	0.340
0.859	0.0887	0.245	0.0891	0.333
0.959	0.0885	0.235	0.0854	0.096

Table 4

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Fording Coal in Water

158.5 mm I.D. Closed Loop Pipeline

June, 1980

Mean Solids Volume Fraction = 0.443

Gamma Ray Absorption Coefficient for Fluid = 0.0839

	Velocity = 2.29 m/s Solids Coefficient = 0.109		Velocity = 2.90 m/s Solids Coefficient = 0.109	
y/D	Slurry Coefficient	Solids Volume fraction	Slurry Coefficient	Solids Volume fraction
0.050	0.1048	0.829	0.1036	0.809
0.150	0.0986	0.630	0.0938	0.459
0.250	0.0903	0.335	0.0890	0.288
0.350	0.0896	0.310	0.0916	0.381
0.450	0.0862	0.189	0.0859	0.178
0.550	0.0821	0.043	0.0848	0.139
0.650	0.0847	0.135	0.0843	0.121
0.750	0.0842	0.117	0.0845	0.128
0.850	0.0839	0.107	0.0838	0.107
0.950	0.0824	0.053	0.0849	0.142

Table 5

Gamma Ray Gauge Concentration Profile Measurements

- 50 mm Coal Valley Coal in Water

263.1 mm I.D. Closed Loop Pipeline

March 1982

Mean Solids Volume Fraction = 0.250

Gamma Ray Absorption Coefficient for Fluid = 0.0809

	Velocity = 2.32 m/s		Velocity = 2.96 m/s	
	Solids Coefficient = 0.110		Solids Coefficient = 0.109	
y/D	Slurry Coefficient	Solids Volume fraction	Slurry Coefficient	Solids Volume fraction
0.050	0.1061	0.866	0.1062	0.900
0.150	0.1018	0.718	0.0988	0.637
0.250	0.0943	0.460	0.0933	0.441
0.350	0.0905	0.330	0.0932	0.438
0.450	0.0908	0.340	0.0897	0.313
0.550	0.0884	0.258	0.0855	0.164
0.650	0.0888	0.271	0.0867	0.206
0.750	0.0870	0.210	0.0889	0.285
0.850	0.0836	0.093	0.0834	0.089
0.950	0.0842	0.113	0.0851	0.149

Table 6

Gamma Ray Gauge Concentration Profile Measurements

- 50 mm Coal Valley Coal in Water

263.1 mm I.D. Closed Loop Pipeline

March 1982

Mean Solids Volume Fraction = 0.350

Gamma Ray Absorption Coefficient for Fluid = 0.0809

	Velocity = 2.38 m/s Solids Coefficient = 0.109		Velocity = 3.05 m/s Solids Coefficient = 0.107	
Y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.050	0.1082	0.972	0.1071	1.004
0.150	0.1005	0.698	0.1025	0.828
0.250	0.0944	0.480	0.0945	0.521
0.350	0.0928	0.423	0.0940	0.502
0.450	0.0925	0.413	0.0914	0.402
0.550	0.0894	0.302	0.0887	0.300
0.650	0.0886	0.274	0.0885	0.291
0.750	0.0885	0.270	0.0900	0.349
0.850	0.0882	0.260	0.0868	0.226
0.950	0.0871	0.221	0.0882	0.280

Table 7

Gamma Ray Gauge Concentration Profile Measurements

-50 mm Coal Valley Coal in Water

263.1 mm I.D. Closed Loop Pipeline

March, 1982

Mean Solids Volume Fraction = 0.450

Gamma Ray Absorption Coefficient for Fluid = 0.0809

	Velocity = 3.41 m/s Solids Coefficient = 0.141		Velocity = 4.06 m/s Solids Coefficient = 0.136	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.056	0.1167	0.568	0.1131	0.554
0.156	0.1119	0.483	0.1073	0.441
0.256	0.1059	0.377	0.1016	0.329
0.356	0.1001	0.274	0.0979	0.257
0.456	0.0963	0.206	0.0959	0.218
0.556	0.0940	0.165	0.0948	0.197
0.656	0.0930	0.147	0.0936	0.173
0.756	0.0926	0.140	0.0932	0.166
0.856	0.0918	0.126	0.0920	0.142
0.956	0.0922	0.133	0.0926	0.154

Table 8

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Raw Judy Creek Coal in Water

495.3 mm I.D. Closed Loop Pipeline

August, 1980

Mean Solids Volume Fraction = 0.250

Gamma Ray Absorption Coefficient for Fluid = 0.0847

	Velocity = 2.44 m/s Solids Coefficient = 0.110		Velocity = 3.05 m/s Solids Coefficient = 0.109	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.056	0.1062	0.850	0.1020	0.712
0.156	0.0990	0.565	0.0988	0.580
0.256	0.0964	0.462	0.0958	0.457
0.356	0.0923	0.300	0.0925	0.321
0.456	0.0914	0.265	0.0908	0.251
0.556	0.0902	0.217	0.0905	0.239
0.656	0.0896	0.194	0.0890	0.202
0.756	0.0897	0.198	0.0896	0.202
0.856	0.0897	0.193	0.0890	0.177
0.956	0.0891	0.174	0.0898	0.210

Table 9

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Fording Coal in Water

495.3 mm I.D. Closed Loop Pipeline

July, 1980

Mean Solids Volume Fraction = 0.320

Gamma Ray Absorption Coefficient for Fluid = 0.0847

	Velocity = 2.48 m/s Solids Coefficient = 0.108		Velocity = 3.16 m/s Solids Coefficient = 0.1055	
y/D	Slurry Coefficient	Solids Volume Fraction	Slurry Coefficient	Solids Volume Fraction
0.056	0.1048	0.863	0.1014	0.803
0.156	0.1024	0.760	0.0994	0.707
0.256	0.0987	0.601	0.0963	0.558
0.356	0.0954	0.459	0.0937	0.433
0.456	0.0936	0.382	0.0930	0.399
0.556	0.0929	0.352	0.0924	0.370
0.656	0.0917	0.300	0.0914	0.322
0.756	0.0917	0.300	0.0909	0.298
0.856	0.0913	0.283	0.0912	0.313
0.956	0.0916	0.296	0.0914	0.322

Table 10

Gamma Ray Gauge Concentration Profile Measurements

-50.8 mm Kaiser Coal in Water

495.3 mm I.D. Closed Loop Pipeline

August, 1980

Mean Solids Volume Fraction = 0.436

Gamma Ray Absorption Coefficient for Fluid = 0.0847

Judy Creek Raw Coal: The coefficient of static friction obtained with a tilting glass tube was 0.32. This comparatively low value is similar to that obtained in the previous investigation with McIntyre bituminous coal of density 1473 kg/m^3. However, experimental headlosses were comparatively high for the Judy Creek coal and this could not be entirely explained on the basis of the higher density. A higher coefficient of kinematic friction (0.48) and an increased viscosity effect were both suggested by the data. The higher coefficient of friction could be attributed to the ash content of the raw coal. Since the ash is likely to have a higher density (and probably a higher coefficient of friction) than the coal, the former is likely to contribute disproportionately to the contact load (high friction) mechanism. Use of a mean density for the coal would result in a higher value of η_s being inferred from the experimental data. The increased viscosity effect was evident from the shape of predicted headloss versus velocity relationship. A relationship of the form

$$(\mu_1/\mu_f) = \exp[1.5\ C_1/(0.2692 - 0.2254\ C_1)] \qquad (7)$$

fitted the data satisfactorily with the values of η_s and C_2 which were chosen. Measurements of the viscosity of the fine portion of these slurries confirmed that indeed the viscosity was substantially higher than that assumed in the previous study and that an expression such as (7) was not unreasonable. This is an important observation since it tends to confirm the approach of the model. Figure 83 shows a test of the model at C_{vt} = 0.25 in the 500 mm pipeline. The concentration distribution predicted at a velocity of 3.4 m/s is compared with the observed (gamma ray) results in the upper diagram. Observed headlosses are compared with predictions from the model in the lower figure. From both sets of results, it can be seen that the model, as modified, gives a fair approximation of the results. Significant deviations are especially evident in the upper figure and these will be discussed later.

Fording Coal: This coal had the lowest density yet tested in this laboratory but a high proportion of coarse particles. The coefficients of static and kinematic friction were very similar but the headloss results suggested reduced viscosities, rather than increased values. Reasonable agreement of predicted and observed headlosses required the viscosity - concentration relationship to be altered to:

$$(\mu_1/\mu_f) = \exp\ [0.5\ C_1/(0.2692 - 0.2254\ C_1)] \qquad (8)$$

with these values of η_s and C_2.

This is also an interesting observation, but one which is more difficult to verify experimentally since low viscosity-low concentration slurries containing coarse particles are difficult to test. It is known that slurries containing particles of broad size distribution usually exhibit lower viscosities than those containing particles of narrow size distribution and this is a possible explanation of the results. A second explanation is of course failure of the model simplifications to apply for particles of this comparatively low density. Figure 84 shows data obtained in the 150 mm pipeline at 1.75 m/s. Only fair agreement between predicted and observed concentration profiles is evident. The good agreement between the headlosses is not entirely fortuitous: it indicates what can be achieved by regarding the coefficients in the model as correlating parameters.

Kaiser Coal: This coal also has a low density and is mined from the same geographical region as the Fording coal. As for the latter, headlosses were low. From the data, it appeared that the same viscosity-concentration relationship could be used but the coefficient of kinematic friction was somewhat lower for this somewhat denser coal. Figure 85 shows that again the model predicts concentration profiles which are reasonable approximations (at 2.5 m/s). However the good agreement of the headloss predictions at low velocities is partly fortuitous since the latter are calculated (in principle) from the concentration profiles.

Comparing Figure 83, 84, and 85, a number of generalizations can be made:

a) The C_1 values (obtained from the set of equations 4) are consistently overpredicted in the upper part of the pipe.

b) Concentration profiles are in fact near-linear in the lower part of the pipe.

c) The limiting concentration in the lower part of the pipe may be very different from the values assumed (0.50 and 0.75) for the present study at values of C_{vt} near 0.25 and 0.45.

It can therefore be concluded that although the model can in fact be made to represent experimental headloss results, further progress will require the concentration profiles to be predicted more satisfactorily than is possible at present. Systematic deviations between predicted and observed headlosses can then be interpreted more satisfactorily. At present, however, the model is most useful for scaleup (or scale-down) of experimental results and for predicting the effect of changes in particle size distribution.

Deposit Velocities: The conventional method for generalizing these determinations is to use F_L defined by

$$F_L = V_c/\sqrt{2gD(S_s-1)} \tag{9}$$

There are few reliable quantitative generalizations of these F_L values for slurries with very broad size distributions and this proved also to be true for the coals. For the 150, 250, and 500 mm pipelines and the -50 mm coals the F_L values were: Judy Creek: 1.19, Fording: 1.39, and Kaiser: 1.34.

The F_L value for Coal Valley coal in the 250 mm pipeline was 0.93. There was considerable scatter in these values which masked any systematic effect of pipe diameter or solids concentration. The increased fines content of the attrition runs did significantly reduce F_L, however. It is interesting that the previous study also showed lower F_L values for the coal of higher density.

An advantage of the mechanistic two layer model is that velocities V_1 and V_2 are predicted simultaneously with headlosses. Since deposition corresponds to formation of a thin layer of solids, it is not surprising that finite values of V_2 were predicted for the (thick) lower layers at $V = V_c$. As progress is made in understanding flow in the lower layer, it may well be possible to eventually predict V_c from this mechanistic approach.

5.3 Degradation tests

The results of these measurements are shown in Figures 86 and 87. Predicted values are also shown; these use the model of Austin and Luckie in the manner described in previous investigations (11, 12). For the size interval between screens of opening d_i and d_{i+1}, the fractional solid content obeys the relationship:

$$\frac{dW_i}{dt} = \sum_{j=i-1}^{1} b_{i,j} \; S_j W_j \; - \; S_i W_i \qquad (5)$$

The rate constants S_i are known to vary with d_i (and the coal) but the breakage distribution function $b_{i,j}$ is assumed to be normalized: viz

$$b_{2,1} = b_{3,2} = b_{i,i-1} \quad \text{etc}$$

The predicted curves were obtained using

$b_{i,i-1} = 0.45$, $b_{i,i-2} = 0.15$, $b_{i,i-3} = 0.05$, $b_{i,j} = 0$ for $j < i-3$. These are similar to the values reported by Karabelas in a simulation study conducted with fine Balmer seam Canadian coal particles in a Couette viscometer (14).

Rate constants used in obtaining the predicted distributions were, for the 150 mm pipeline:

$$S_i = 0.0054\, f(d_i) \exp(-0.003t)$$

with $f(d_i) = 1$ for $d_i > 0.21$ mm

$f(d_i) = (d_i/0.21)$ for $d_i < 0.21$ mm

with t measured in minutes and d_i in mm.

For the 500 mm pipeline,

$$S_i = 0.0027\, f(d_i) \exp(-0.015t)$$

with $f(d_i) = 1$ for $d_i > 0.84$ mm

$f(d_i) = (d_i/0.84)$ for $d_i < 0.84$ mm.

Previous experience with short test pipelines suggests that most degradation occurs in the pumps. Since the 500 mm pipeline was somewhat longer, part of the reason for the lower rate of degradation was the smaller number of passages through the pump. However, there is a residual effect due to equipment size which is very significant and important. Since degradation is undesirable, Figures 86 and 87 suggest larger scale equipment may be justified. A similar indication was obtained in the small scale tests using lignite.

The time variation for S_i for both systems was observed in earlier studies with lignite and is probably due to slight changes (rounding) of particle shape as a result of abrasion.

6. CONCLUSIONS

1) Coarse coal containing particles up to 50 mm in diameter were pipelined without any major operating problems at concentrations in the 50 to 60% by weight range.

2) Pressure gradients due to flow are higher than for conventional fine grind (14 mesh top size) coal in water slurries. However, the pressure gradients are not so high as to rule out coarse coal in water pipelines for short distances.

3) Particle degradation rates decrease with increasing pump and pipe size although the mechanism appears to be the same.

4) For any one coal, the empirical correlation involving ϕ_t and ψ^{-1} is useful for the range of pipe and particle diameters considered here.

5) The two-layer model of K.C. Wilson is applicable to these flows. Coefficients of kinematic friction are not necessarily determinable in simple tilting tests with glass tubes however.

6) Even at high solids concentration and low velocities, no constant-composition lower layer is observed.

7) The two-layer model is appropriate for scaleup and other extensions of experimental results.

8) Further studies are desirable to improve the method of predicting the solids concentration distribution for coarse particles and for mixtures of broad size distribution.

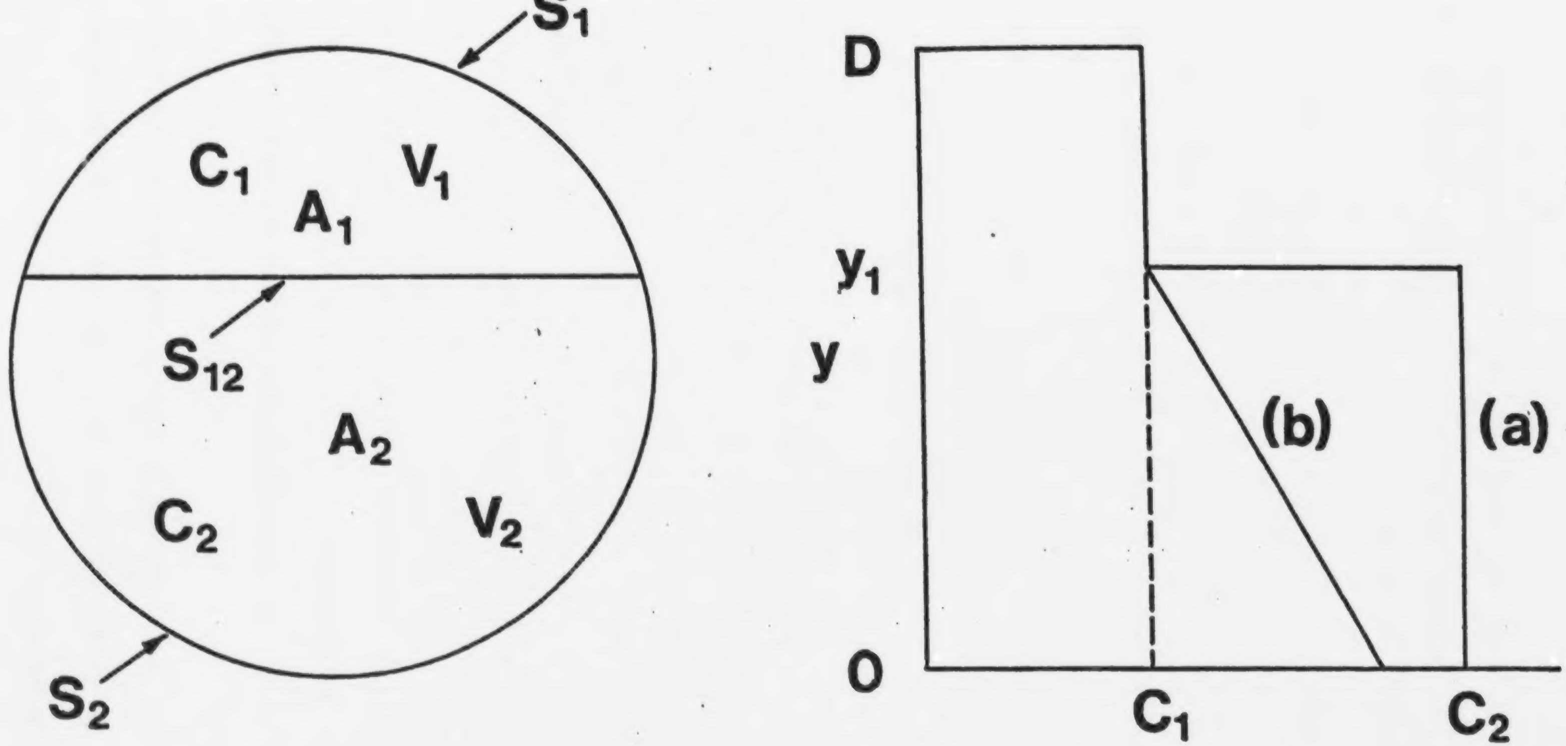
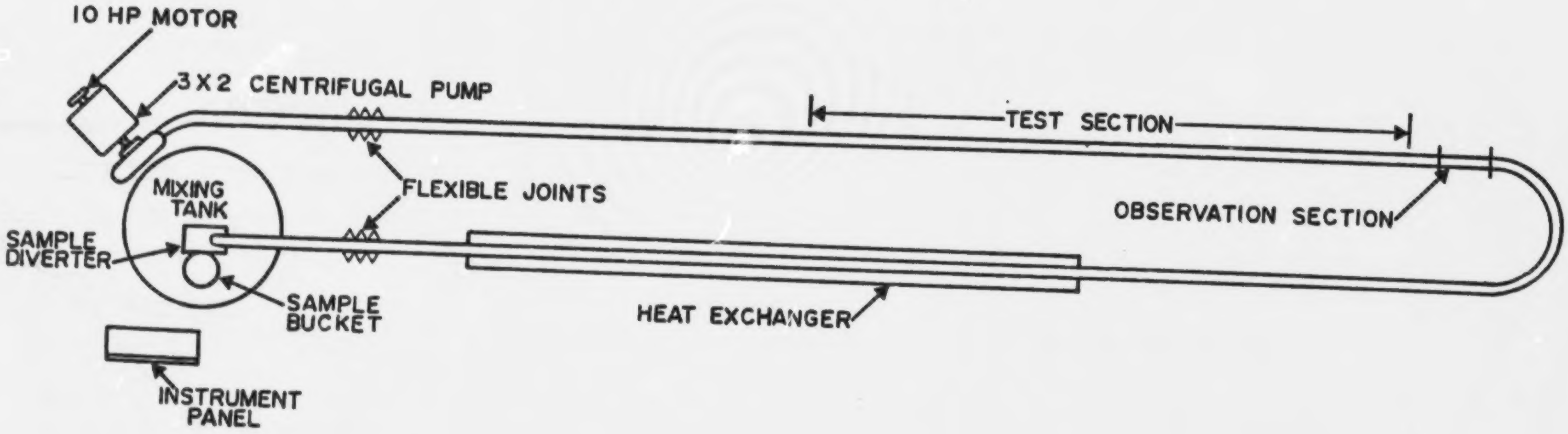
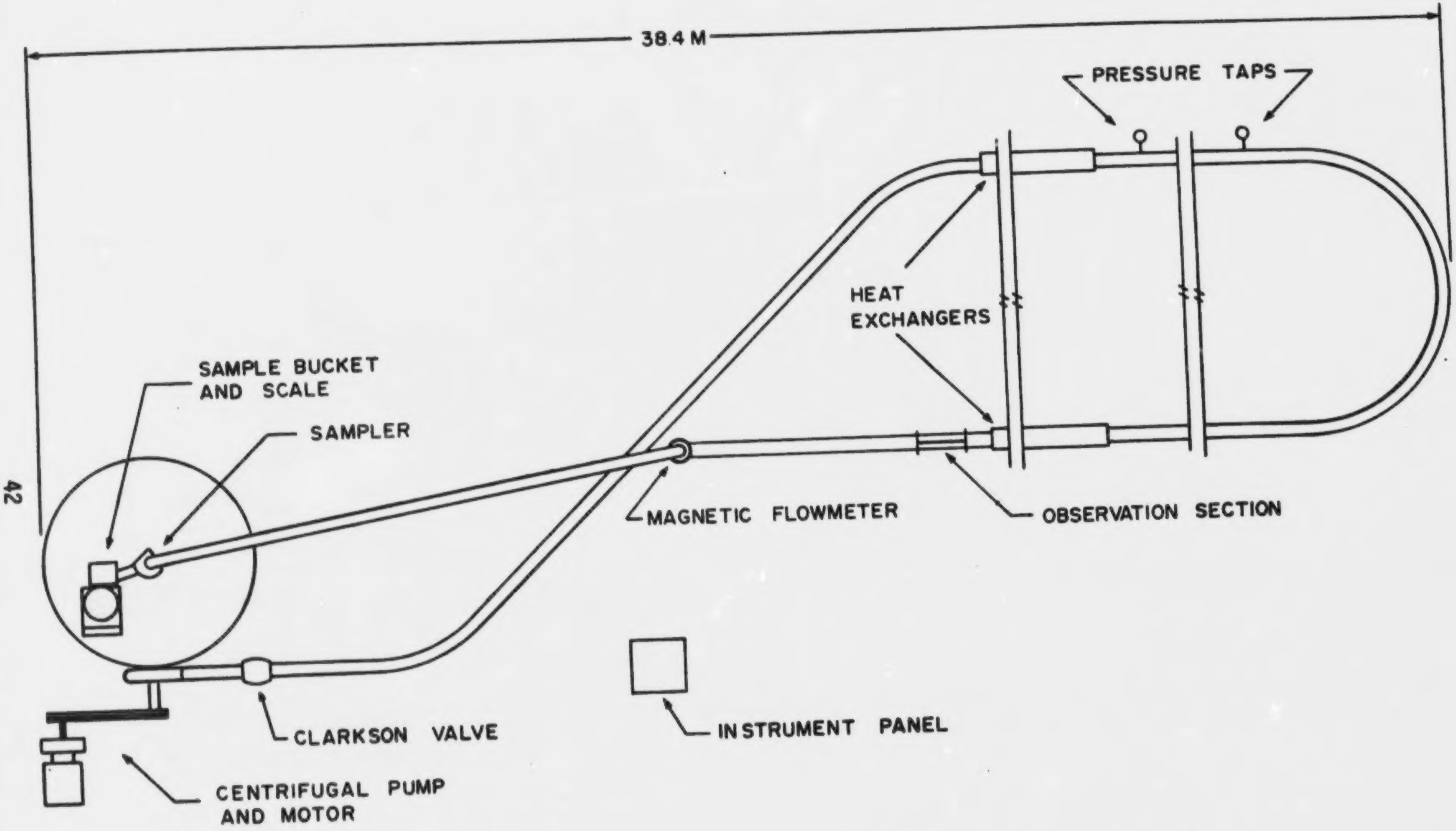

S_1
C_1
A_1
V_1
S_{12}
A_2
C_2
V_2
S_2
D
y_1
y
(b)
(a)
O
C_1
C_2

Figure 1 Two layer model of coarse particle flow


10 HP MOTOR
3 X 2 CENTRIFUGAL PUMP
TEST SECTION
MIXING TANK
FLEXIBLE JOINTS
OBSERVATION SECTION
SAMPLE DIVERTER
SAMPLE BUCKET
HEAT EXCHANGER
INSTRUMENT PANEL

50 mm OPEN PIPELINE LOOP
SCHEMATIC DIAGRAM

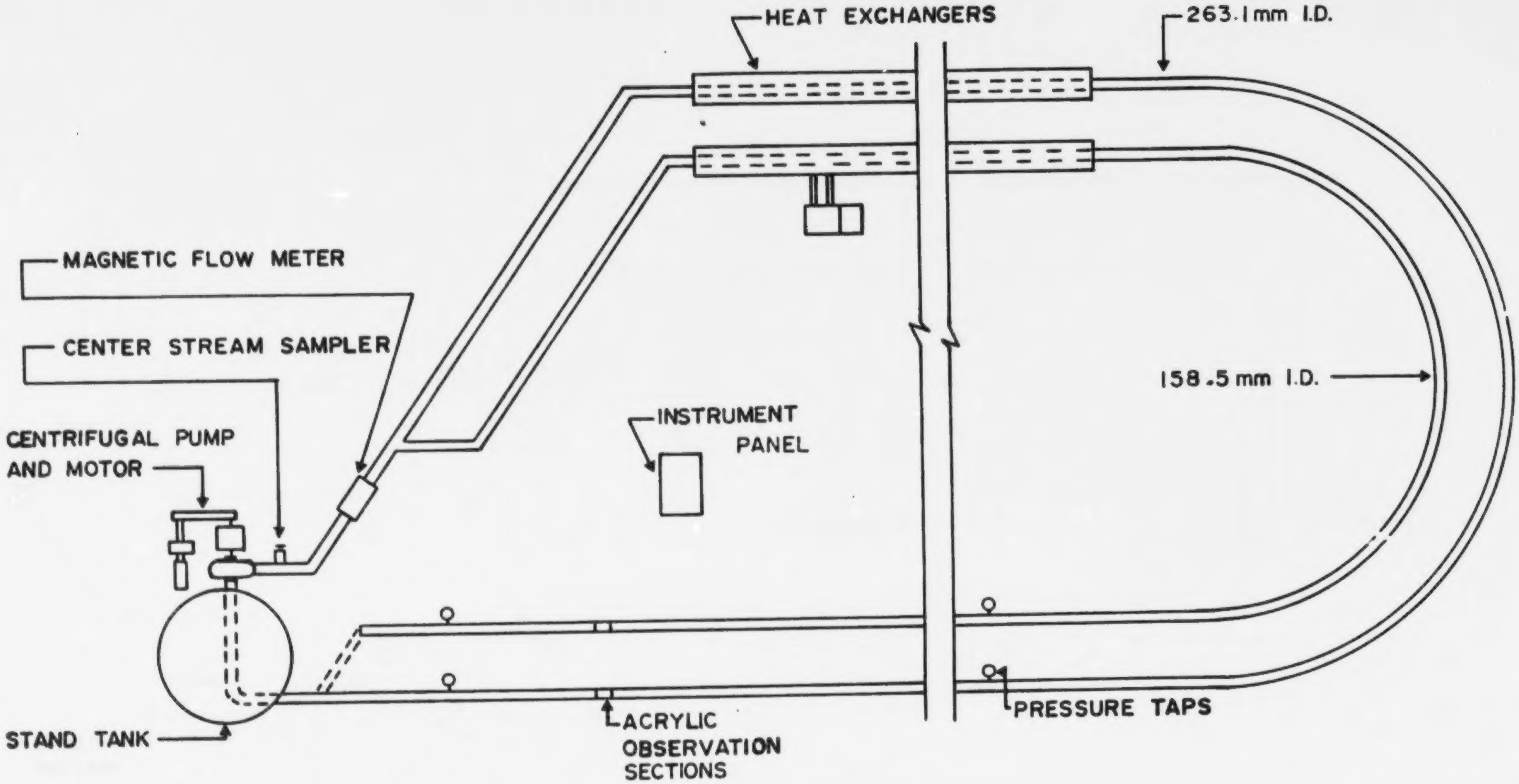
Figure 2


38.4 M
PRESSURE TAPS
HEAT EXCHANGERS
SAMPLE BUCKET AND SCALE
SAMPLER
MAGNETIC FLOWMETER
OBSERVATION SECTION
INSTRUMENT PANEL
CLARKSON VALVE
CENTRIFUGAL PUMP AND MOTOR

SCHEMATIC DIAGRAM

108 mm CLOSED PIPELINE LOOP

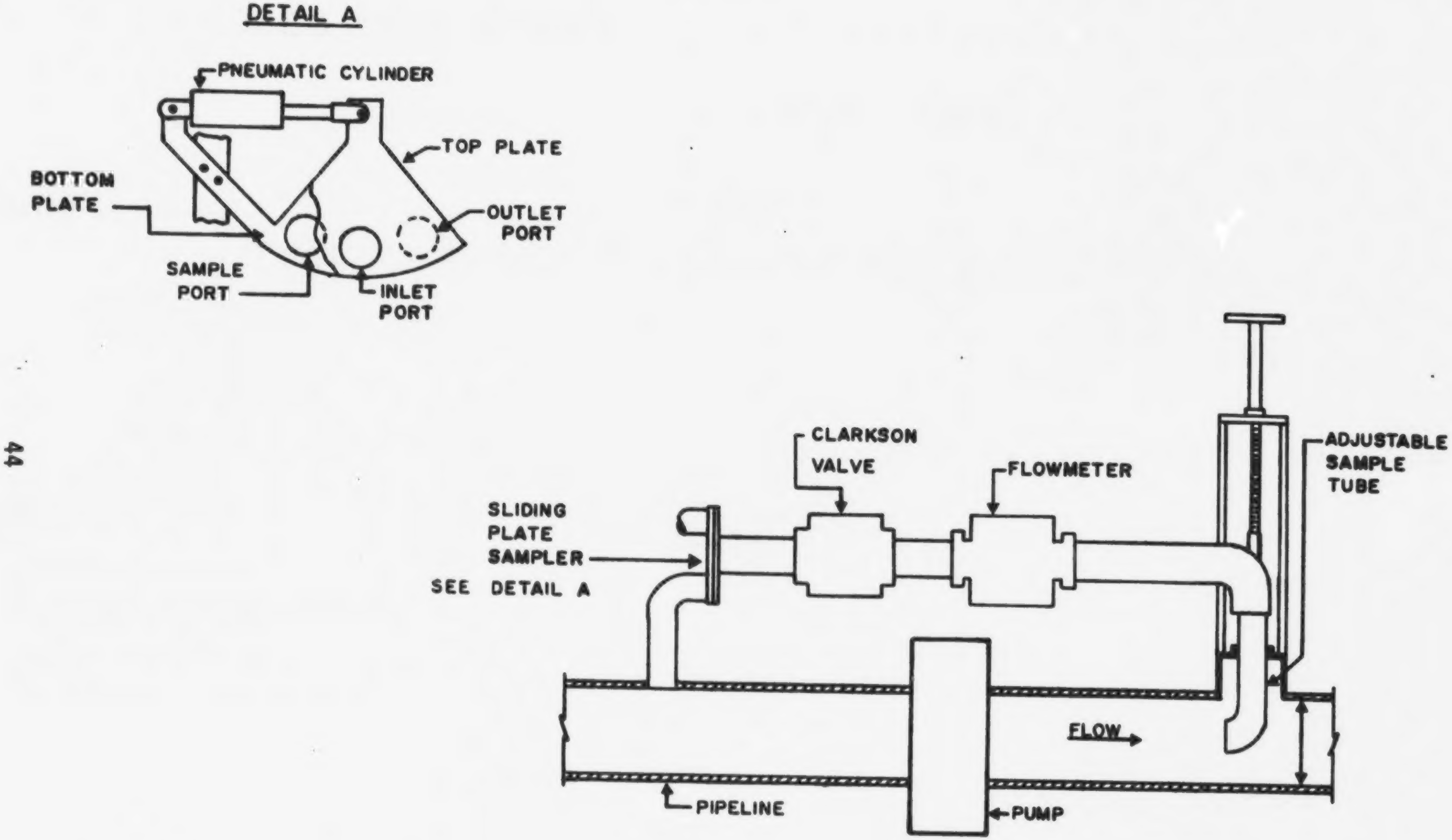
Figure 3


HEAT EXCHANGERS
263.1 mm I.D.
MAGNETIC FLOW METER
CENTER STREAM SAMPLER
CENTRIFUGAL PUMP
AND MOTOR
INSTRUMENT
PANEL
158.5 mm I.D.
STAND TANK
ACRYLIC
OBSERVATION
SECTIONS
PRESSURE TAPS

SCHEMATIC DIAGRAM

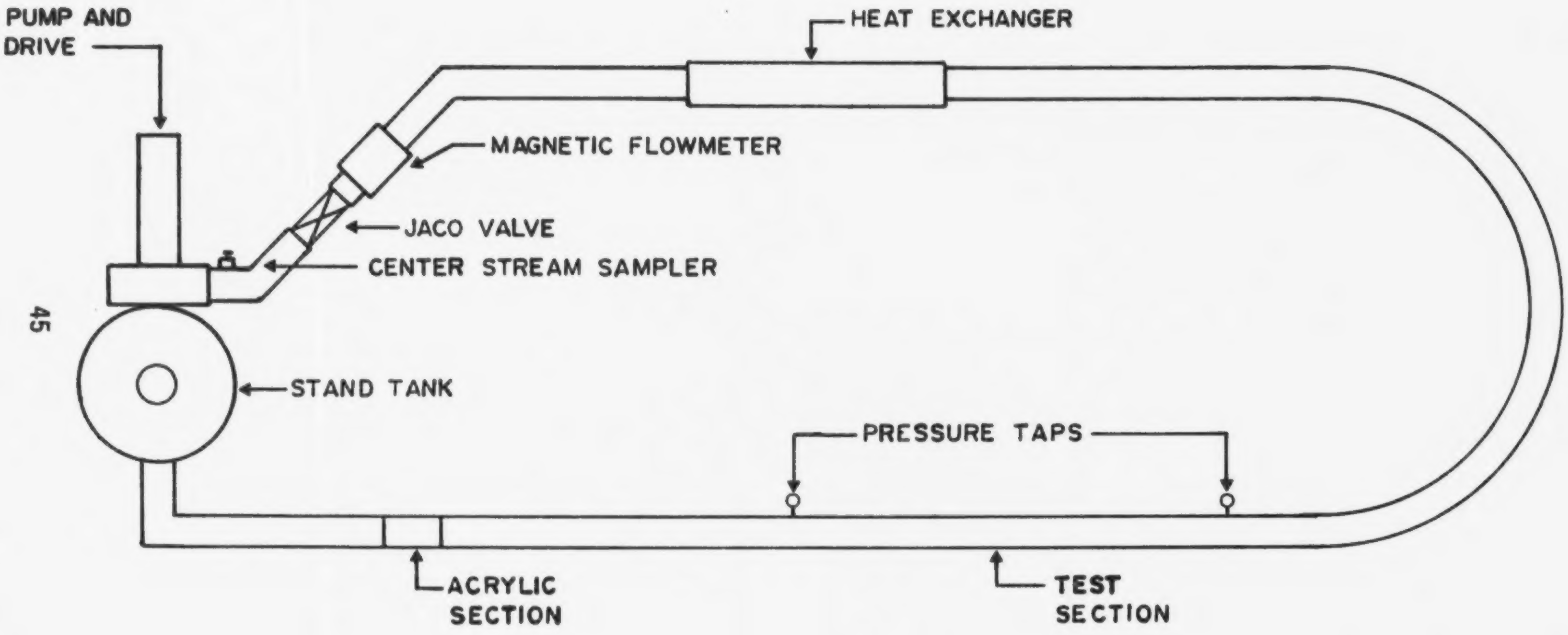
CLOSED LOOP SLURRY PIPELINES (263.1 mm & 158.5 mm)

Figure 4


DETAIL A
PNEUMATIC CYLINDER
TOP PLATE
BOTTOM PLATE
OUTLET PORT
SAMPLE PORT
INLET PORT
CLARKSON VALVE
FLOWMETER
ADJUSTABLE SAMPLE TUBE
SLIDING PLATE SAMPLER
SEE DETAIL A
FLOW
PIPELINE
PUMP

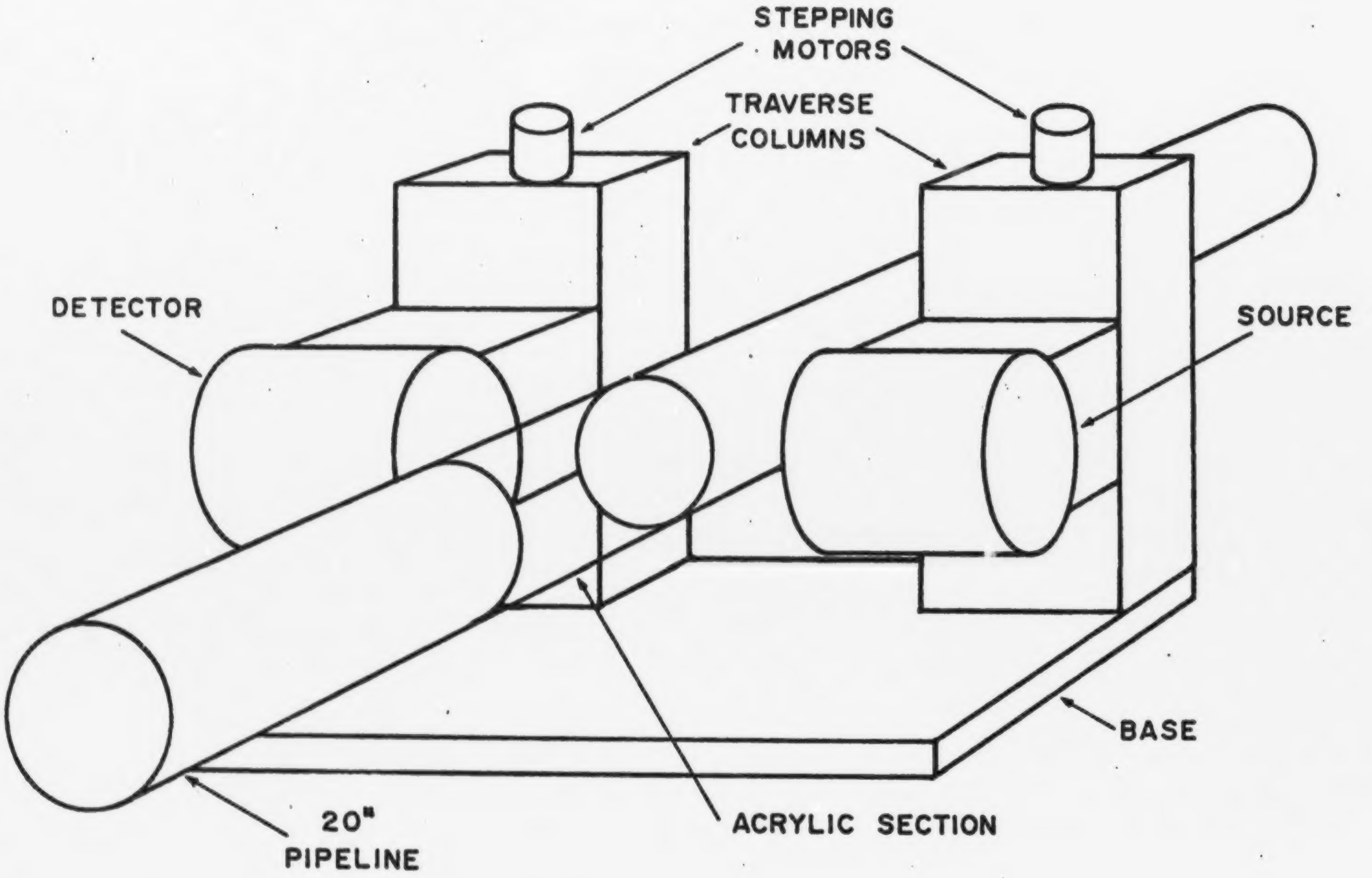
102 mm CENTER STREAM SAMPLER

Figure 5


PUMP AND DRIVE
HEAT EXCHANGER
MAGNETIC FLOWMETER
JACO VALVE
CENTER STREAM SAMPLER
STAND TANK
PRESSURE TAPS
ACRYLIC SECTION
TEST SECTION

500 mm PIPELINE LOOP

Figure 6


STEPPING MOTORS
TRAVERSE COLUMNS
DETECTOR
SOURCE
BASE
20" PIPELINE
ACRYLIC SECTION

GAMMA RAY DENSITY METER

Figure 7

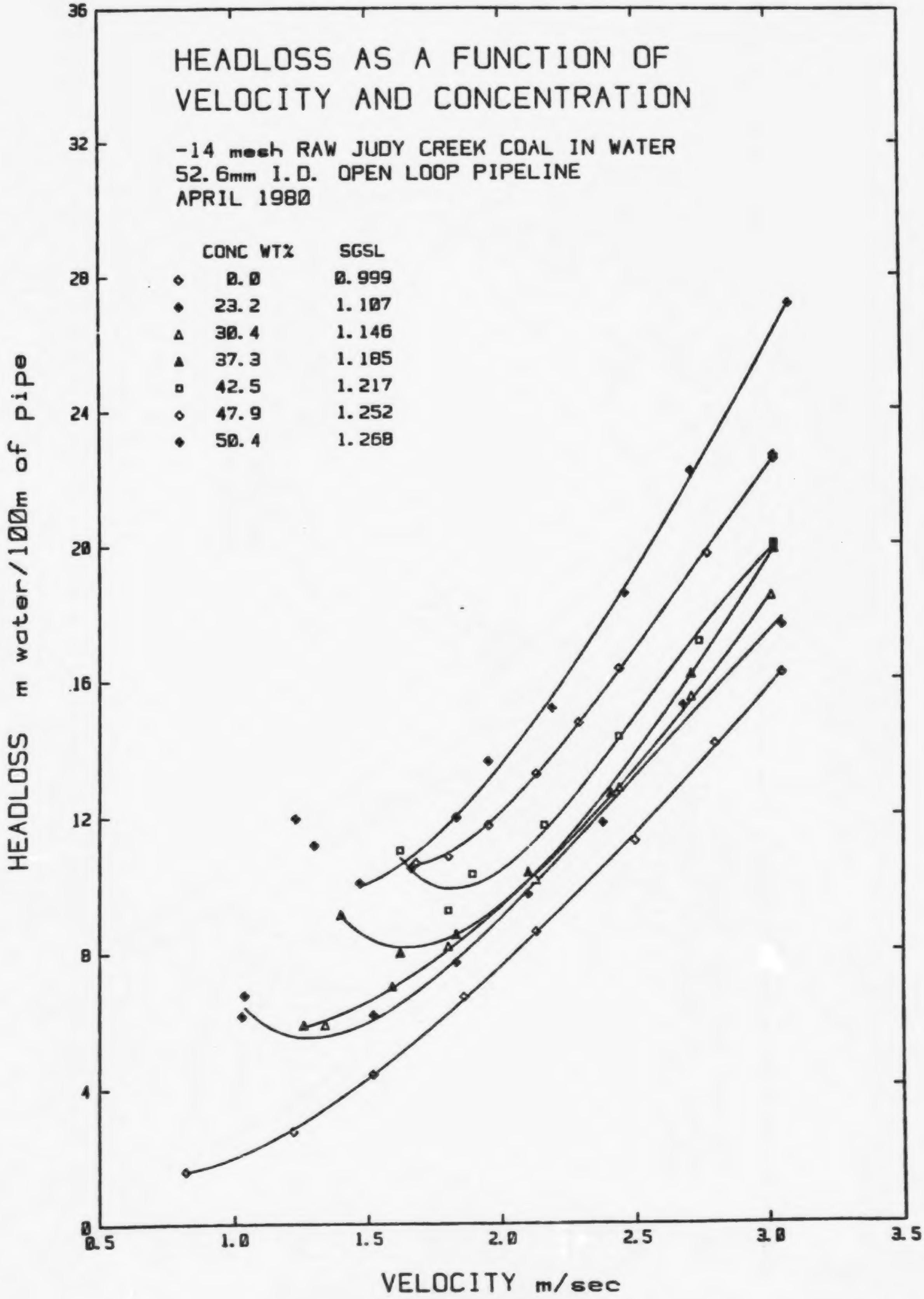
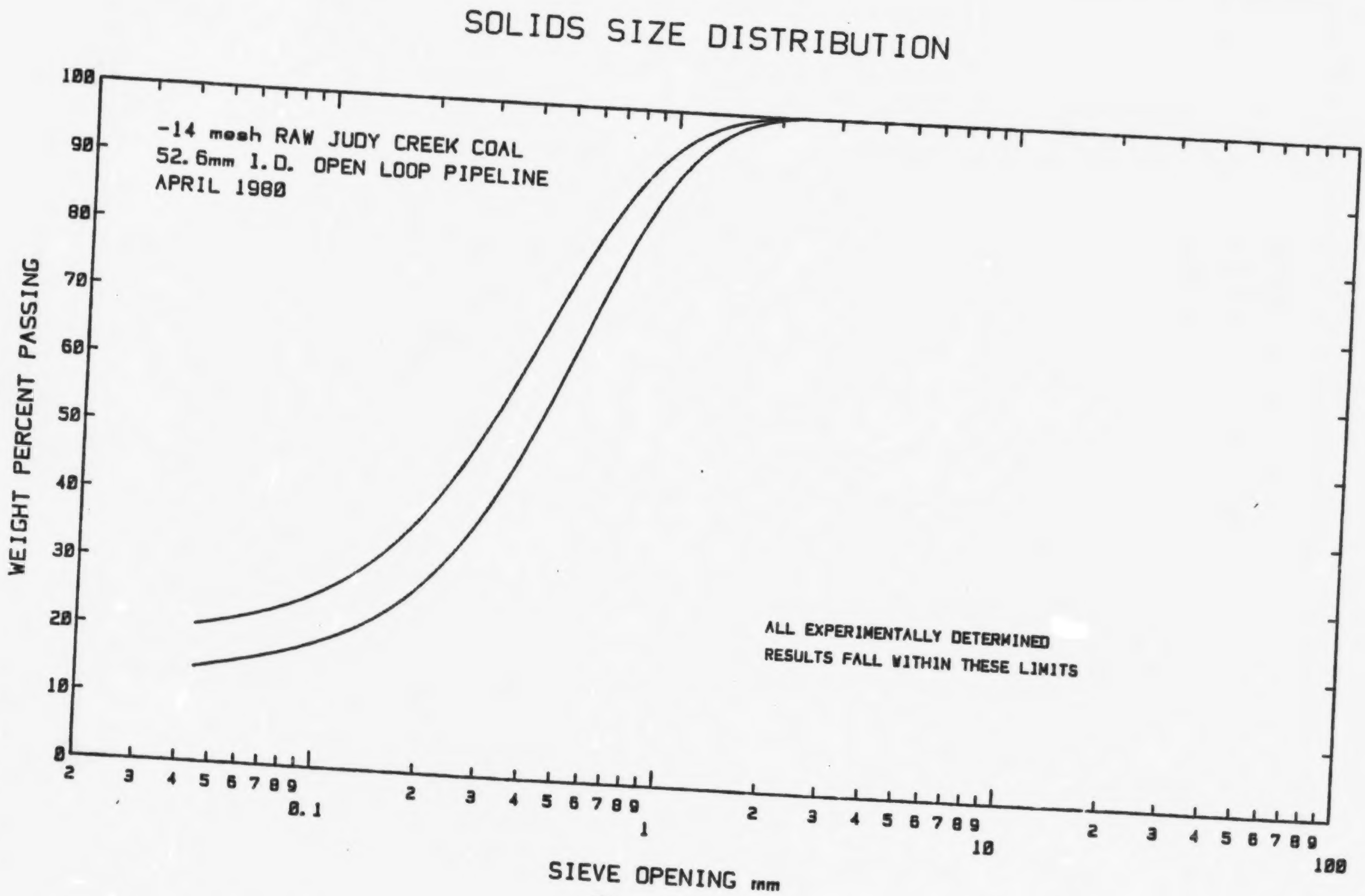

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-14 mesh RAW JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
APRIL 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 23.2 1.107
△ 30.4 1.146
▲ 37.3 1.185
□ 42.5 1.217
◇ 47.9 1.252
◆ 50.4 1.268
HEADLOSS m water/100m of pipe
0
4
8
12
16
20
24
28
32
36
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 8



SOLIDS SIZE DISTRIBUTION

Figure 9

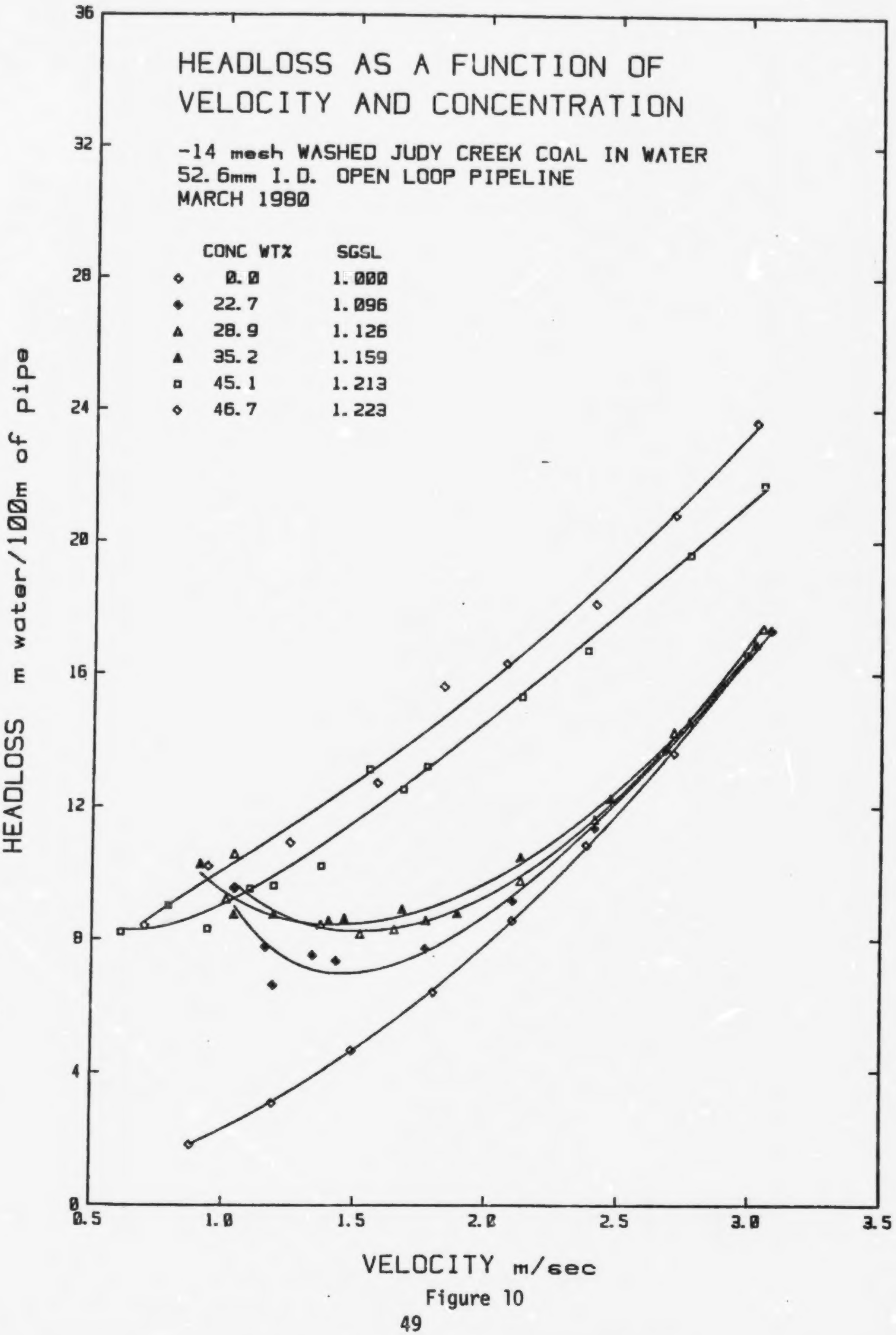

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-14 mesh WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980
CONC WT%
SGSL
◇ 0.0 1.000
◆ 22.7 1.096
△ 28.9 1.126
▲ 35.2 1.159
□ 45.1 1.213
◇ 46.7 1.223
HEADLOSS m water/100m of pipe
0
4
8
12
16
20
24
28
32
36
VELOCITY m/sec
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 10

SOLIDS SIZE DISTRIBUTION

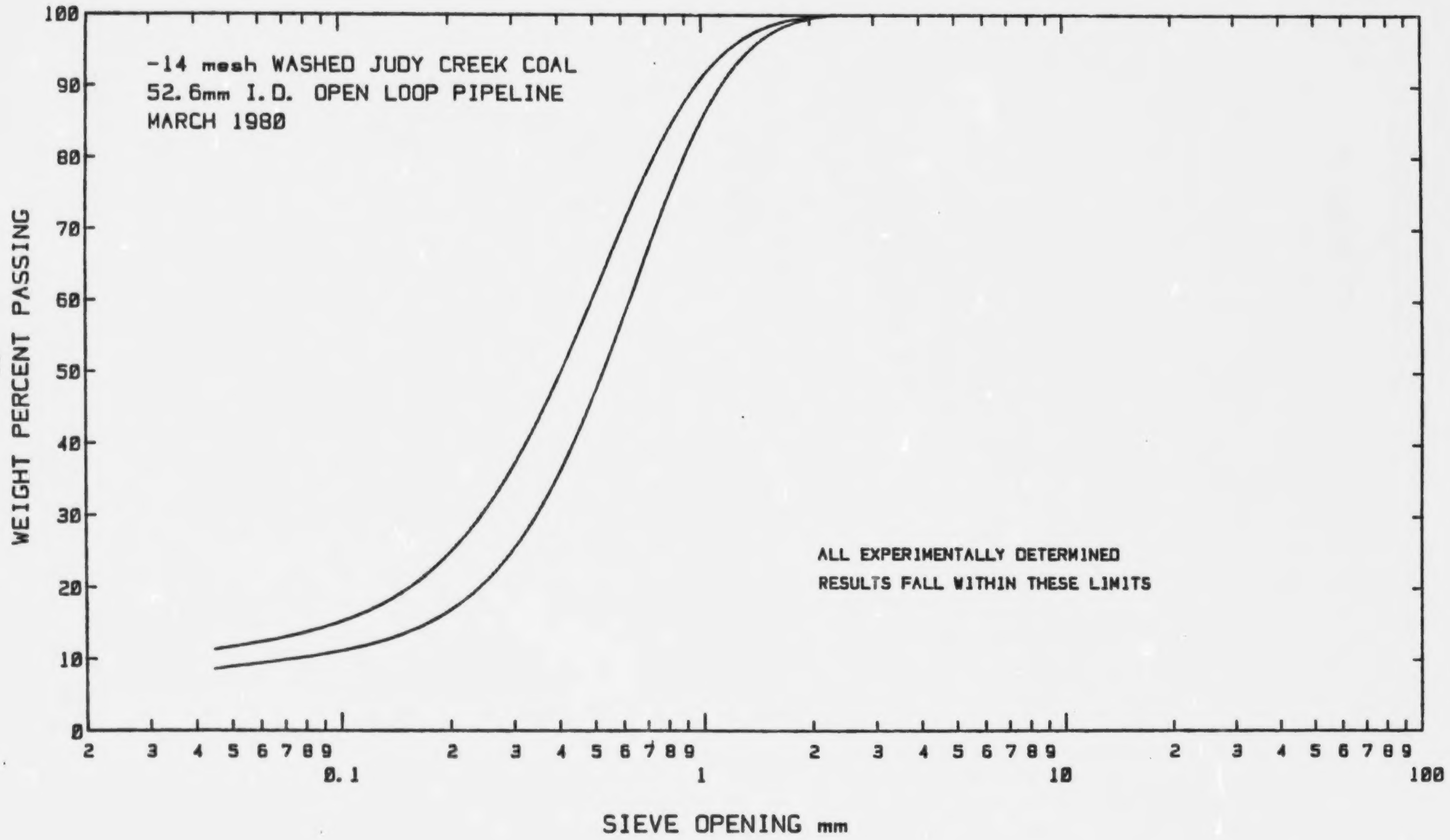


Figure 11

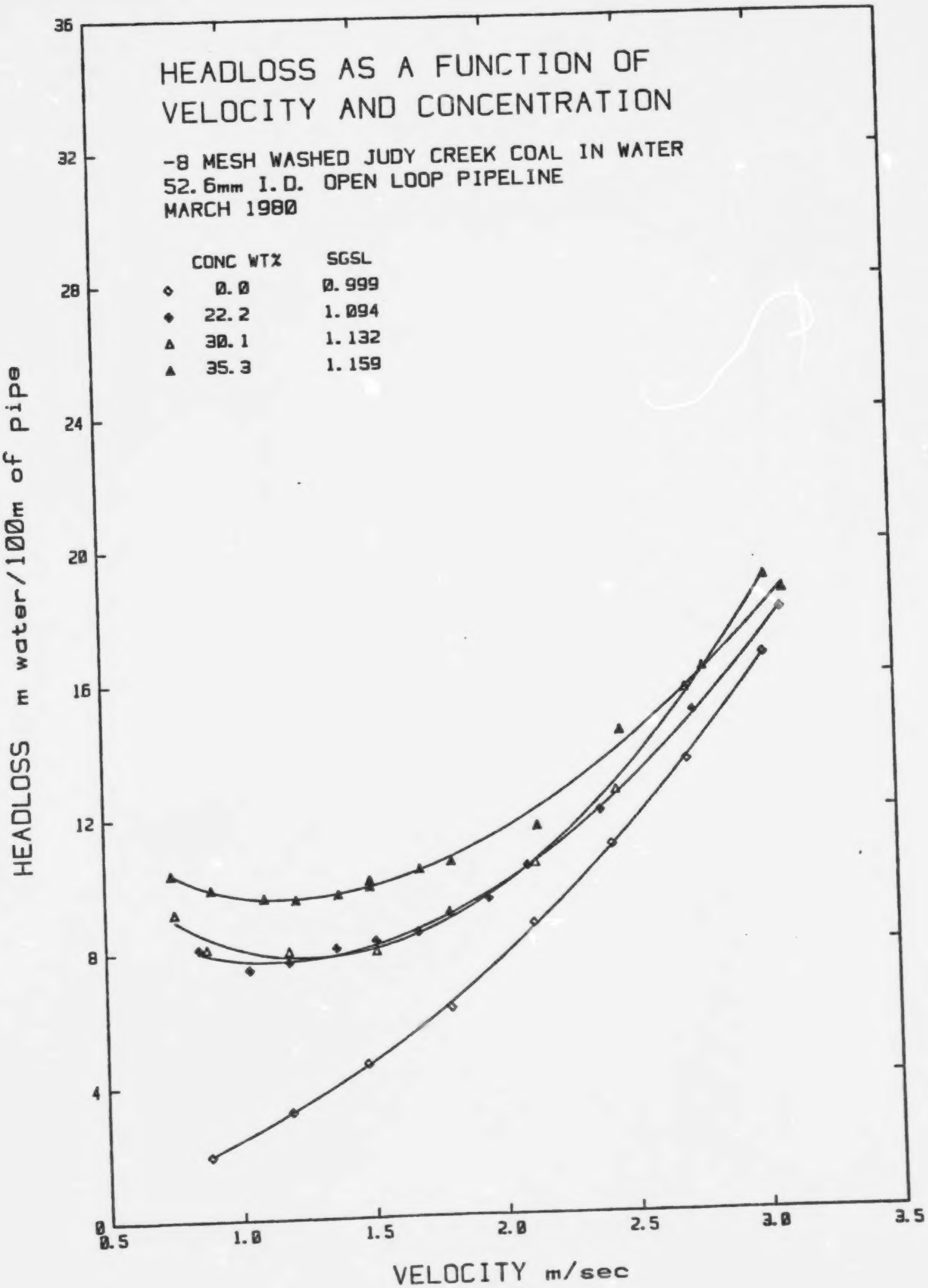

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-8 MESH WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980
CONC WT%
SGSL
◇ 0.0 0.999
◆ 22.2 1.094
△ 30.1 1.132
▲ 35.3 1.159
HEADLOSS m water/100m of pipe
0
4
8
12
16
20
24
28
32
36
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 12

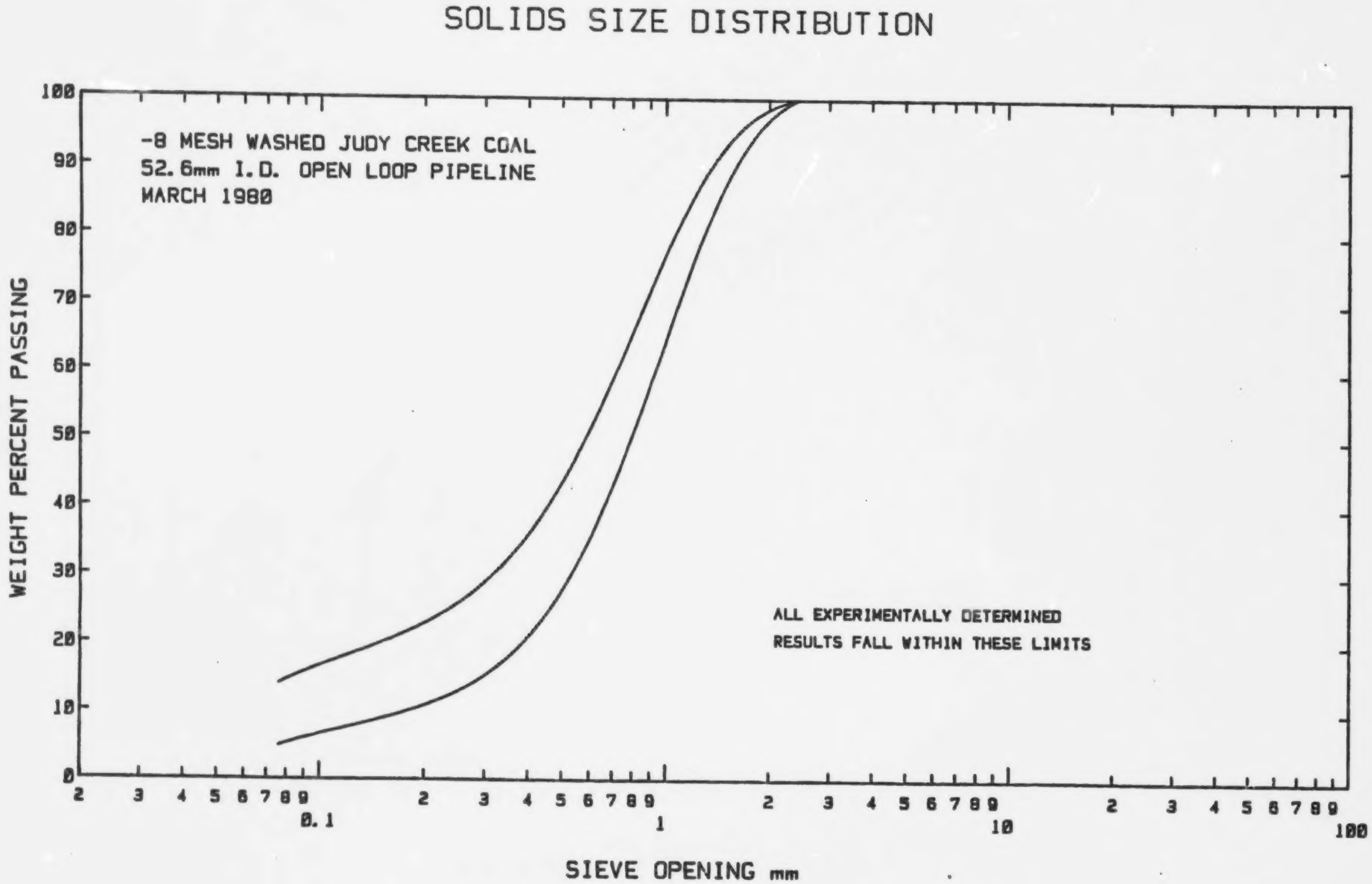

SOLIDS SIZE DISTRIBUTION

Figure 13

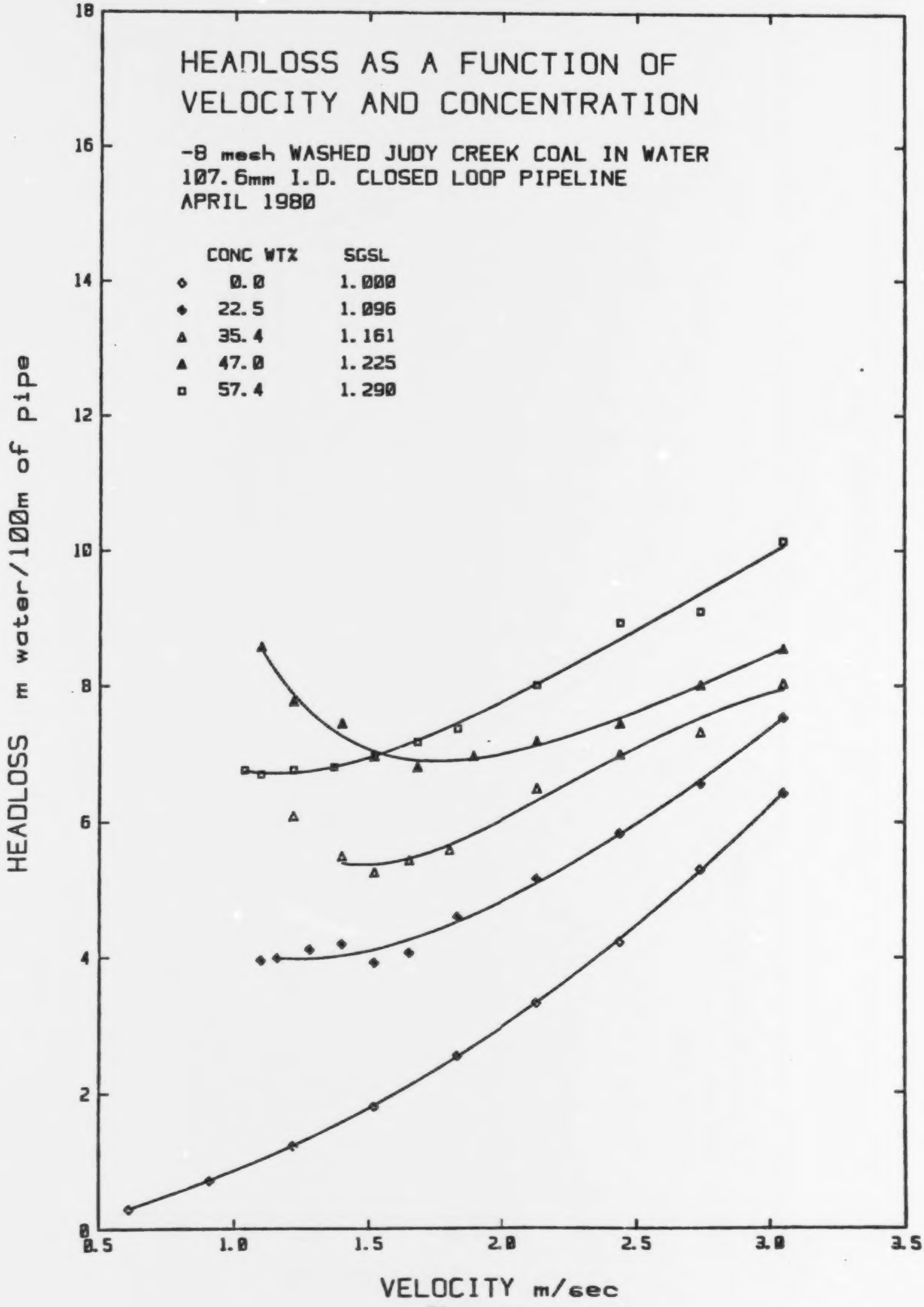
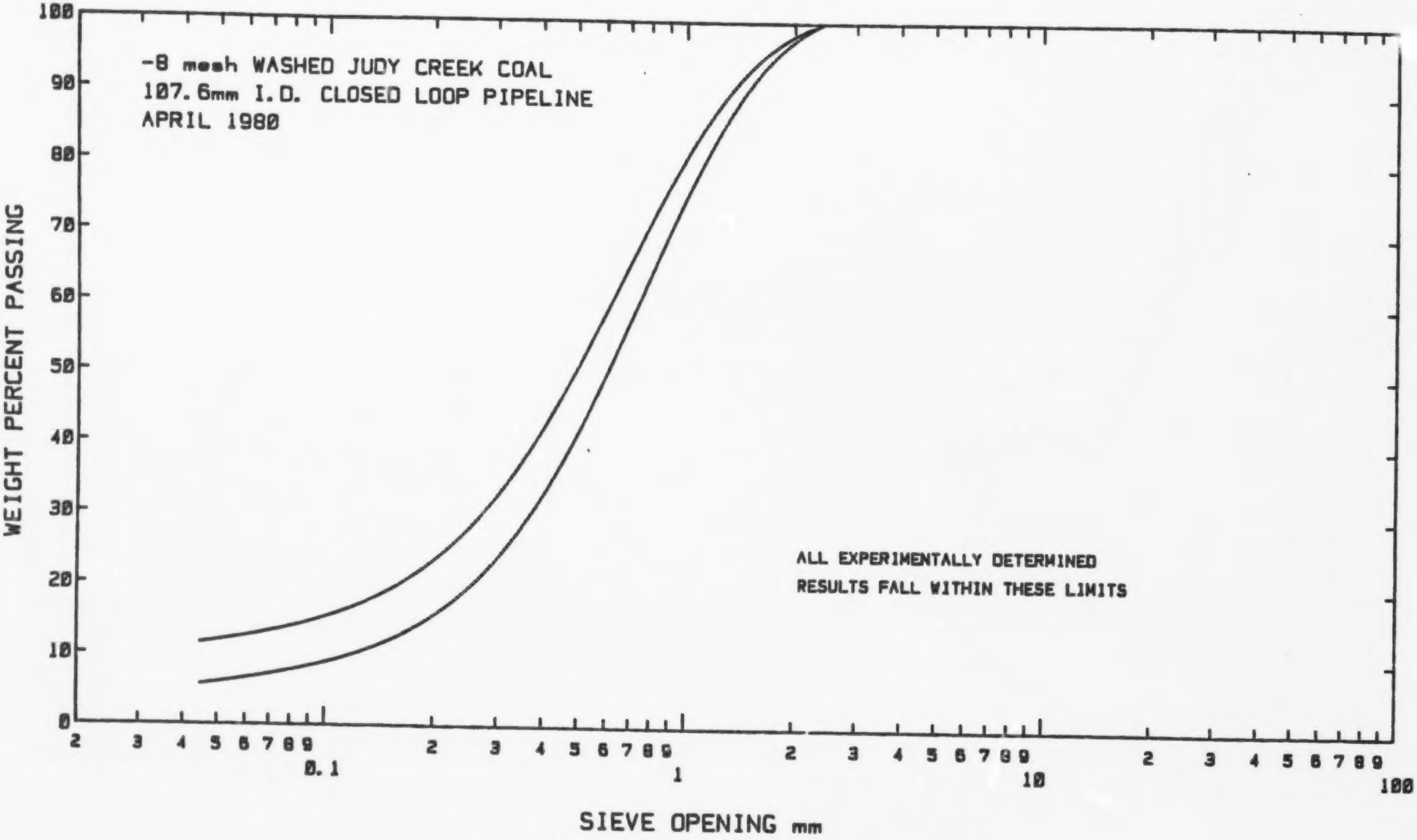

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-8 mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980
CONC WT% SGSL
◇ 0.0 1.000
◆ 22.5 1.096
△ 35.4 1.161
▲ 47.0 1.225
□ 57.4 1.290
HEADLOSS m water/100m of pipe
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 14



SOLIDS SIZE DISTRIBUTION

Figure 15

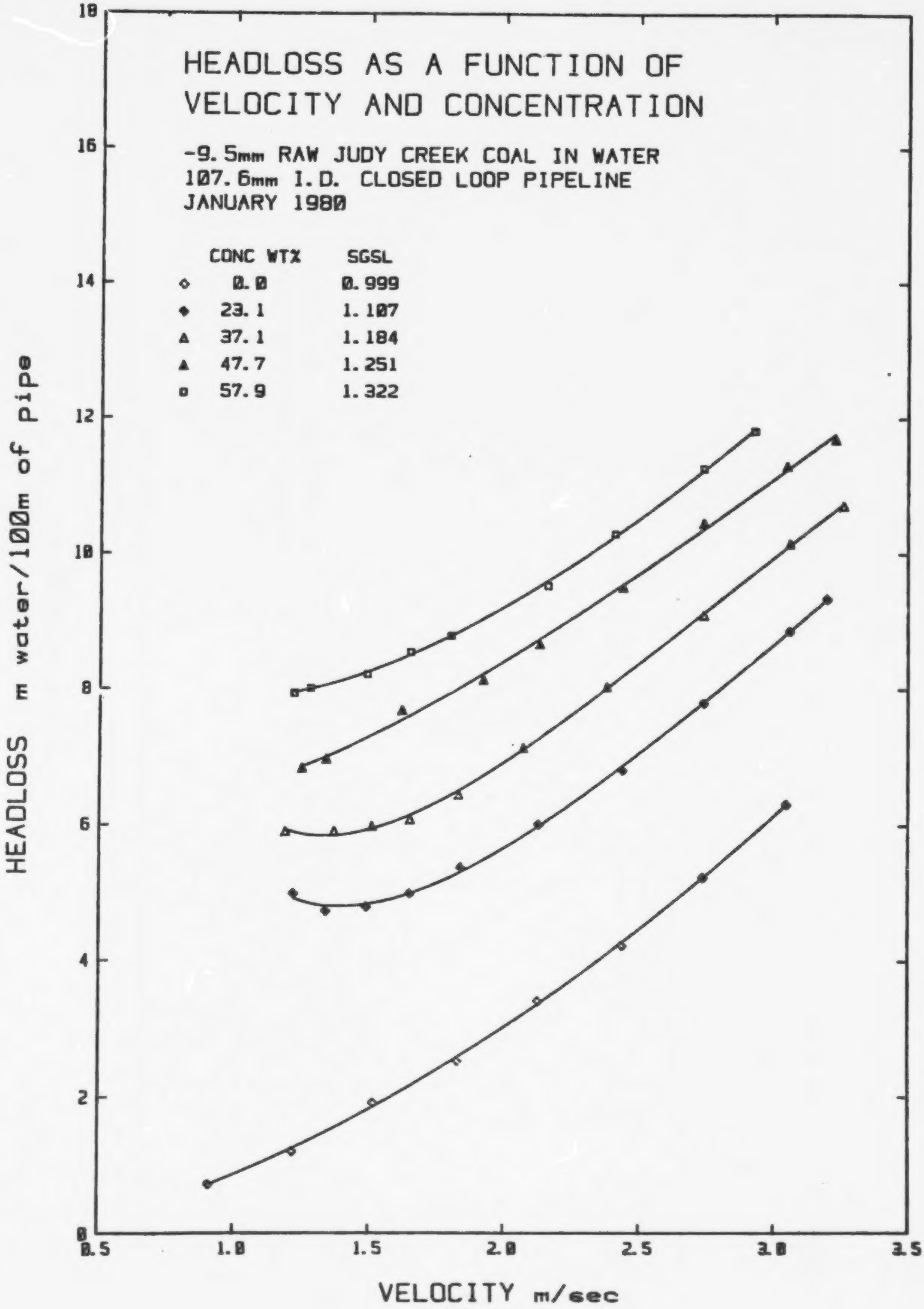

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-9.5mm RAW JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 23.1 1.107
△ 37.1 1.184
▲ 47.7 1.251
□ 57.9 1.322
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 16

SOLIDS SIZE DISTRIBUTION

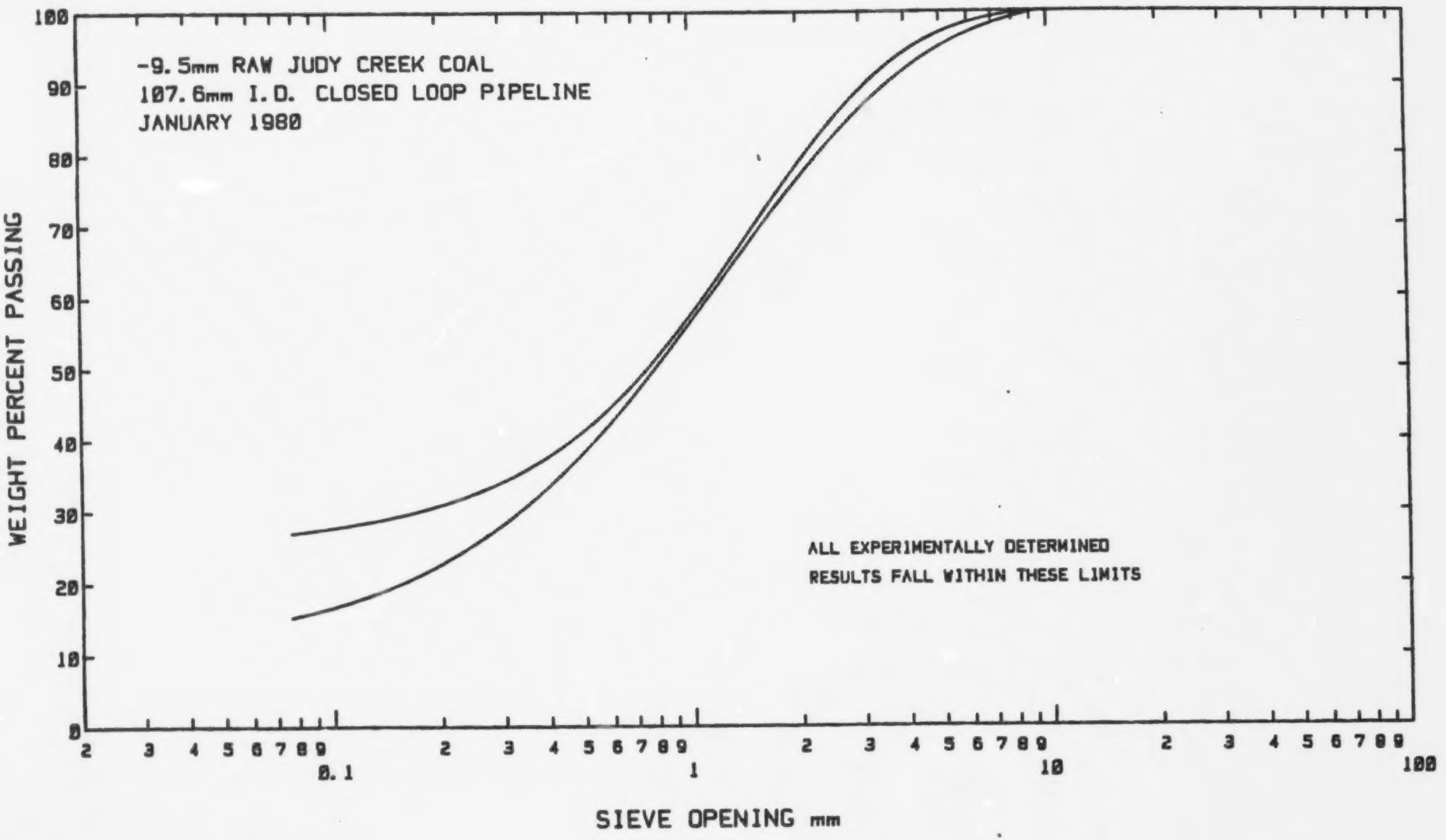


Figure 17

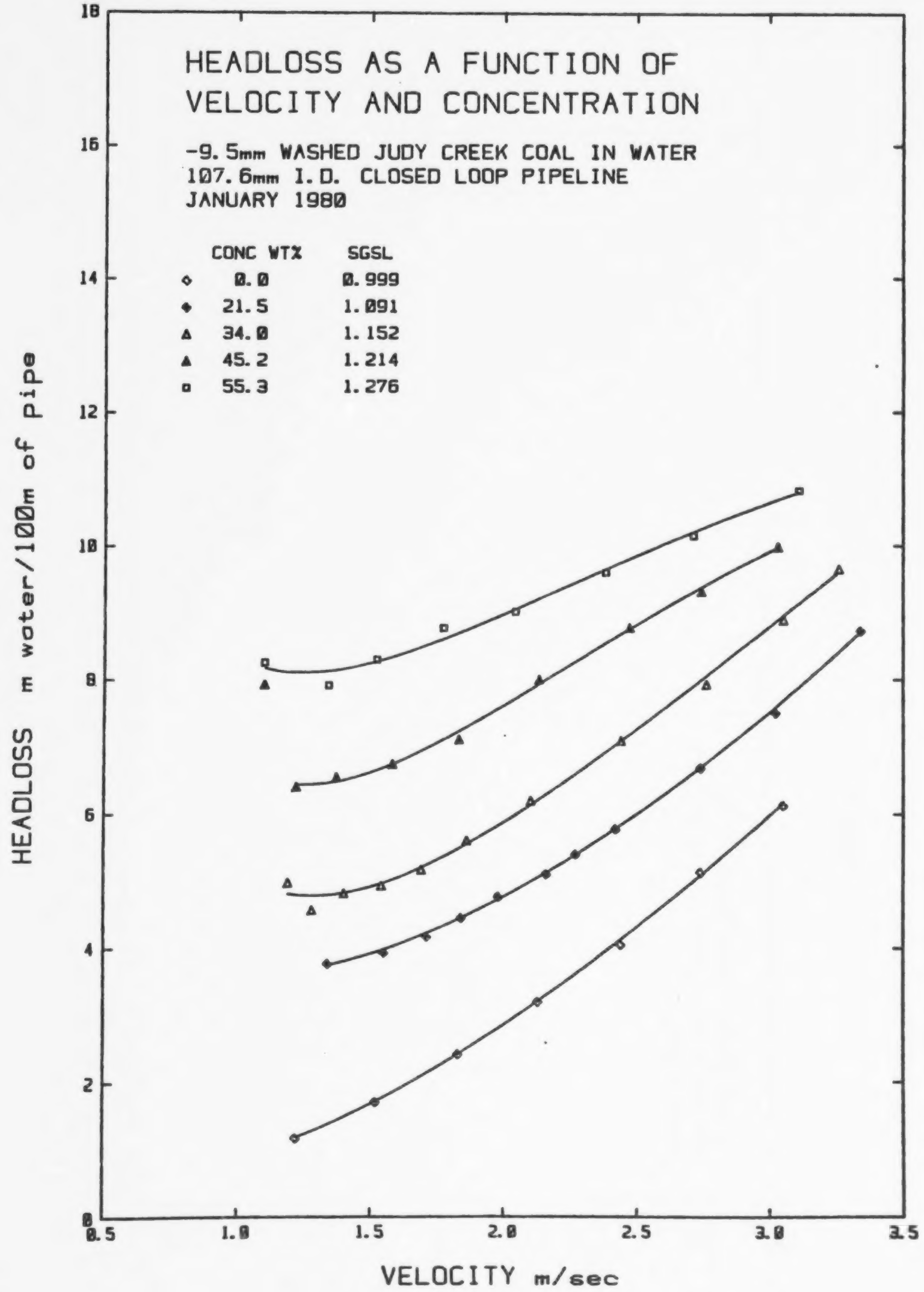

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-9.5mm WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 21.5 1.091
△ 34.0 1.152
▲ 45.2 1.214
□ 55.3 1.276
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 18

SOLIDS SIZE DISTRIBUTION

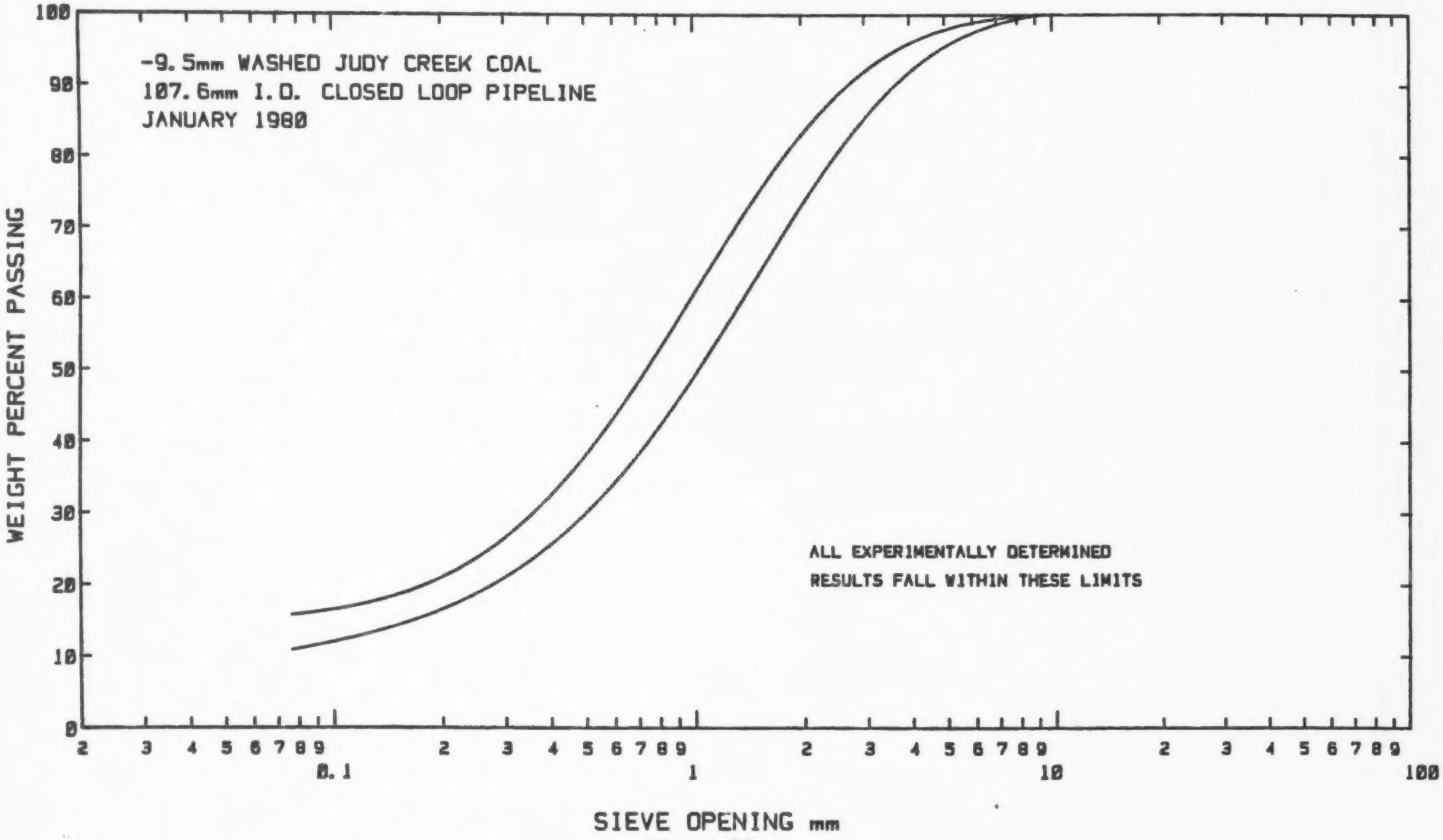


Figure 19

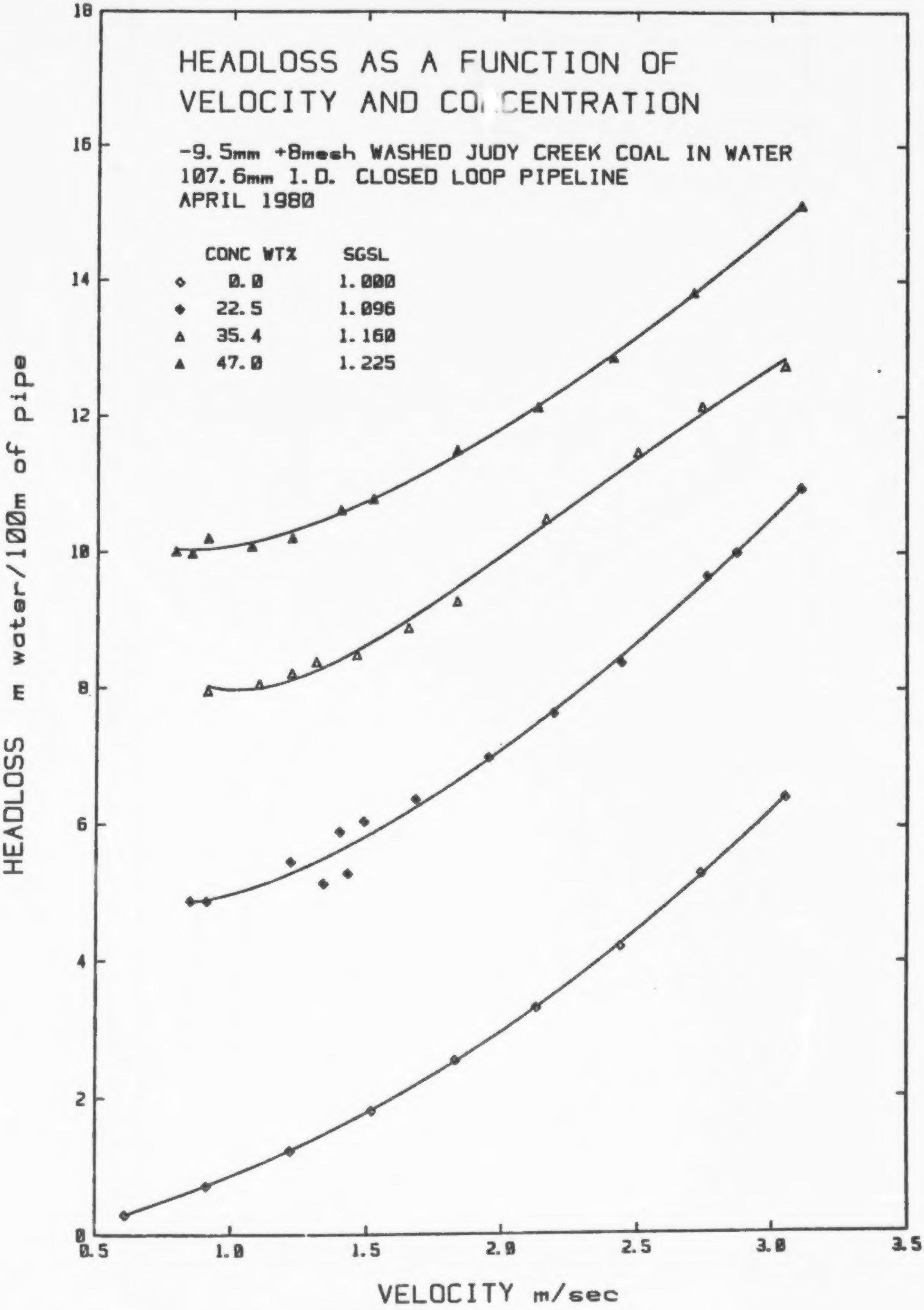
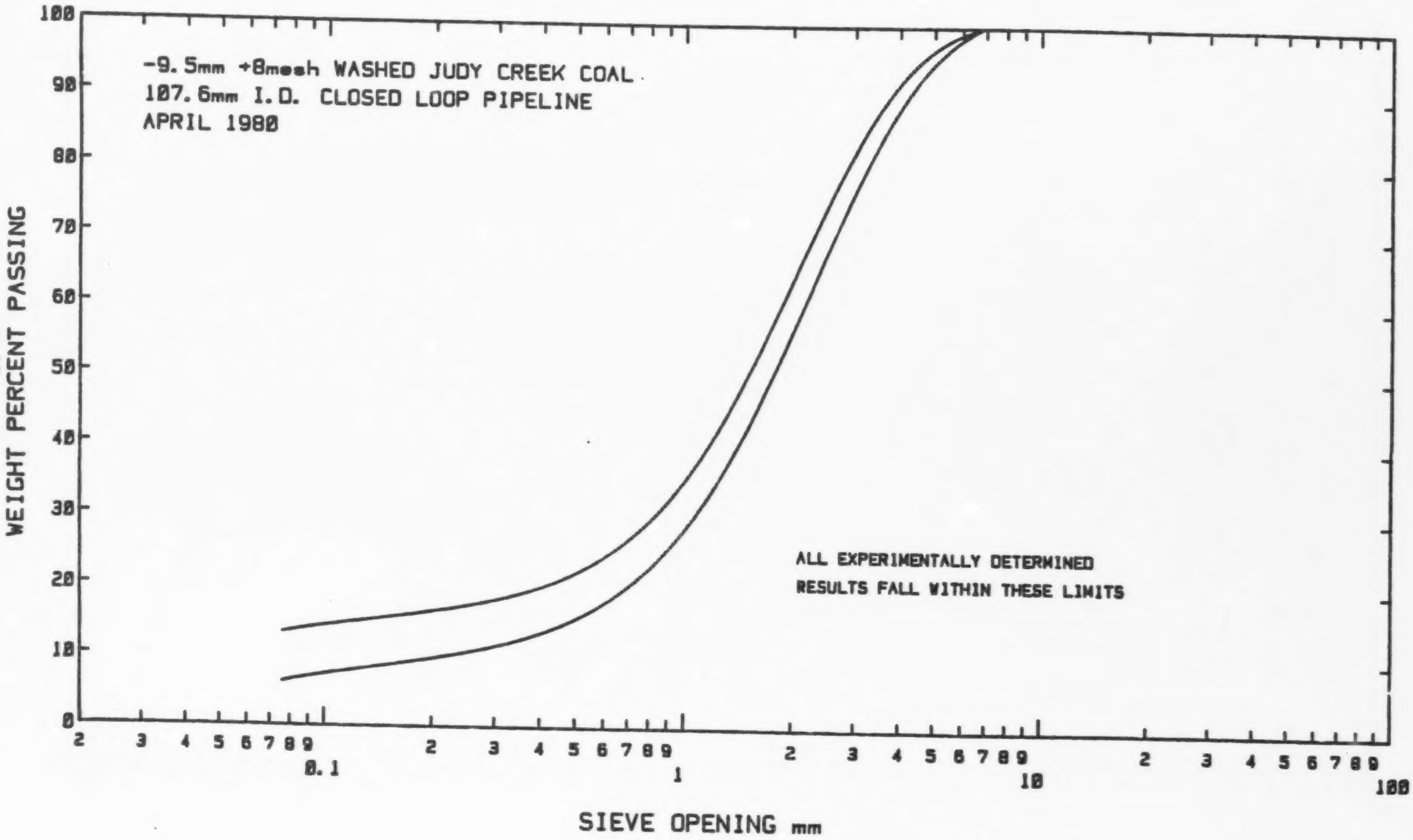

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-9.5mm +8mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980
CONC WT% SGSL
◇ 0.0 1.000
◆ 22.5 1.096
△ 35.4 1.160
▲ 47.0 1.225
HEADLOSS m water/100m of pipe
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 20



SOLIDS SIZE DISTRIBUTION

Figure 21

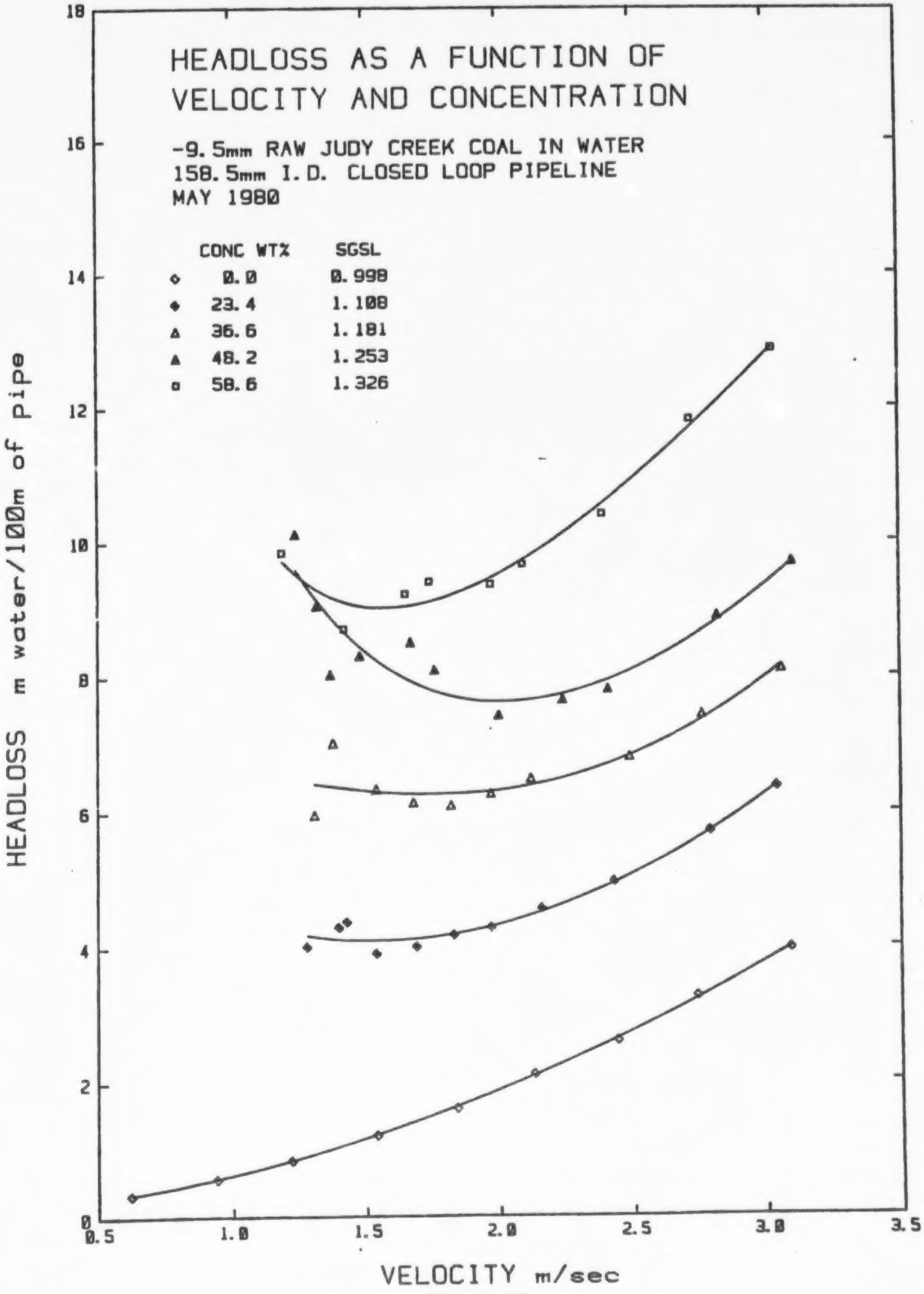
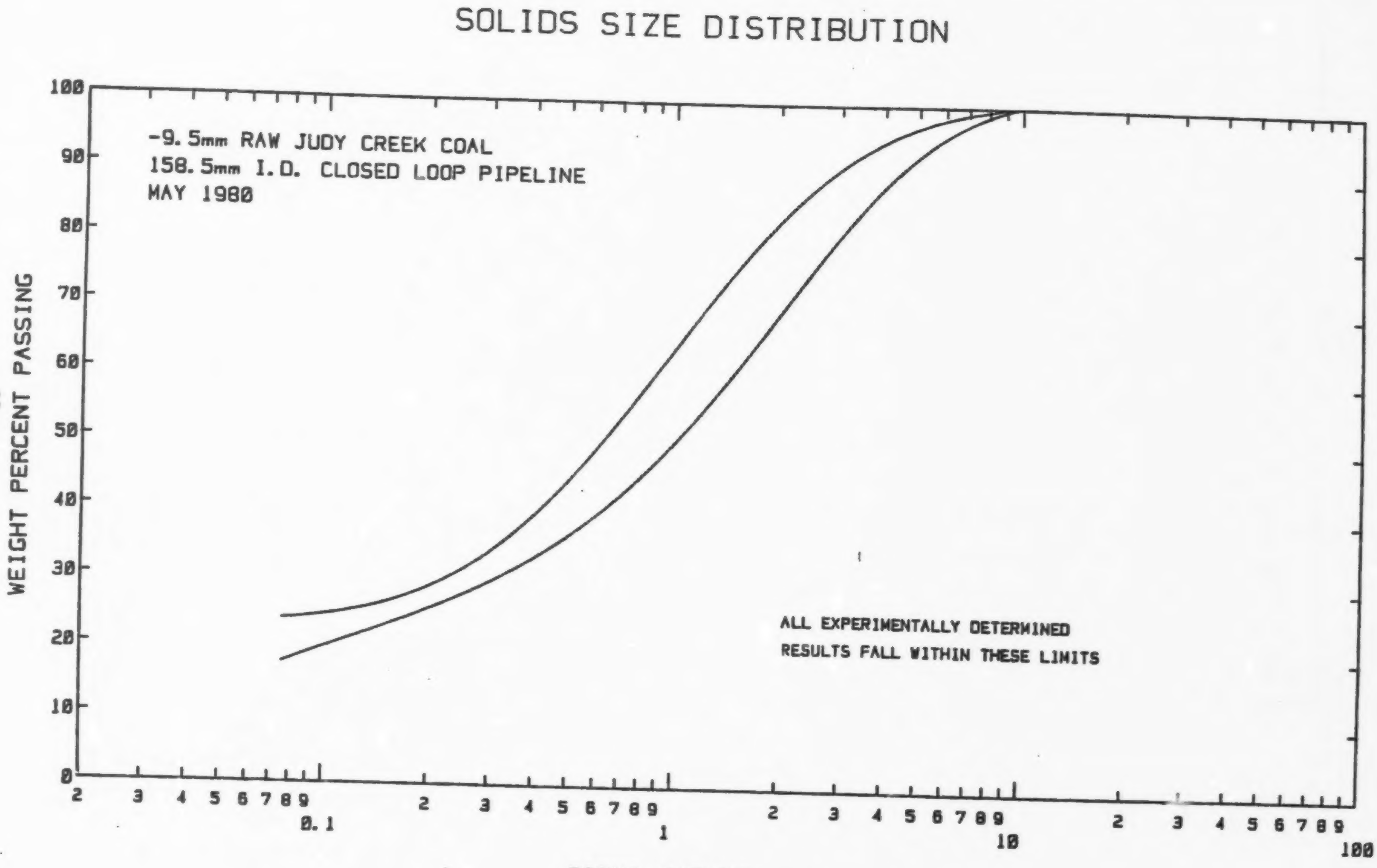

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-9.5mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980
CONC WT%
SGSL
◇ 0.0 0.998
◆ 23.4 1.108
△ 36.6 1.181
▲ 48.2 1.253
□ 58.6 1.326
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 22



SOLIDS SIZE DISTRIBUTION

Figure 23

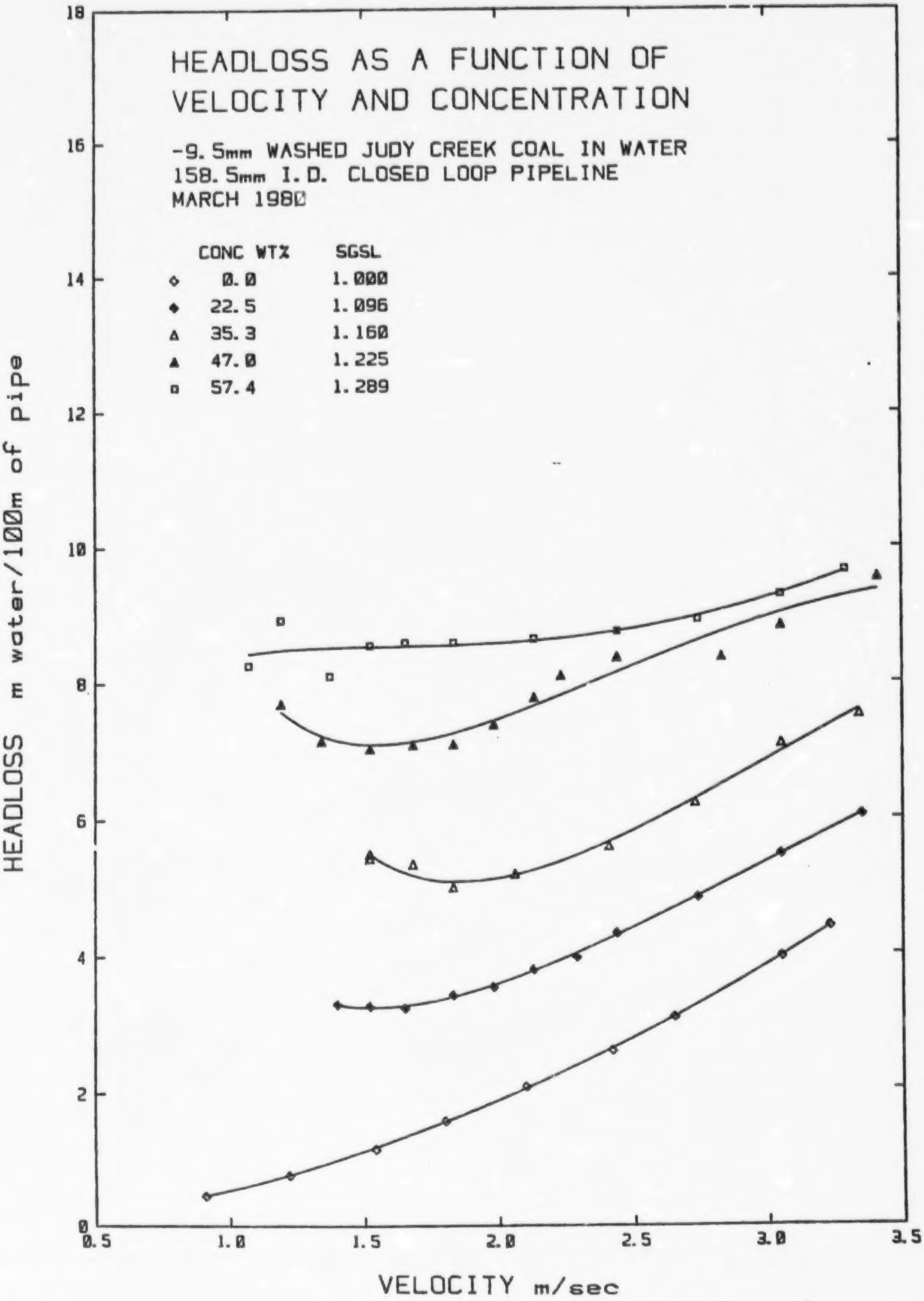

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-9.5mm WASHED JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MARCH 1980
CONC WT% SGSL
◇ 0.0 1.000
◆ 22.5 1.096
△ 35.3 1.160
▲ 47.0 1.225
□ 57.4 1.289
HEADLOSS m water/100m of pipe
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 24

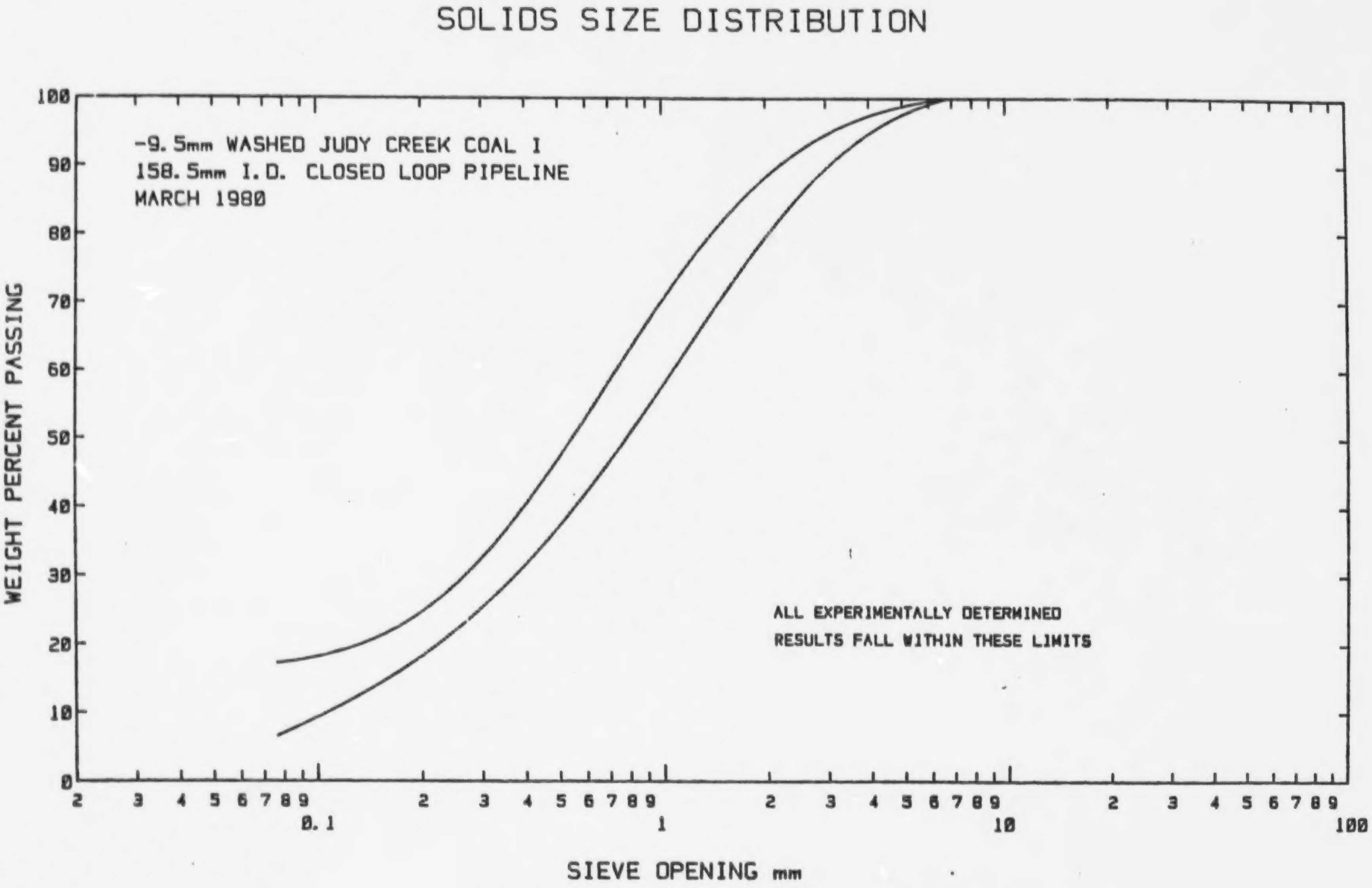

SOLIDS SIZE DISTRIBUTION
-9.5mm WASHED JUDY CREEK COAL I
158.5mm I.D. CLOSED LOOP PIPELINE
MARCH 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
SIEVE OPENING mm
2
3
4
5
6
7
8
9
0.1
1
10
100

Figure 25

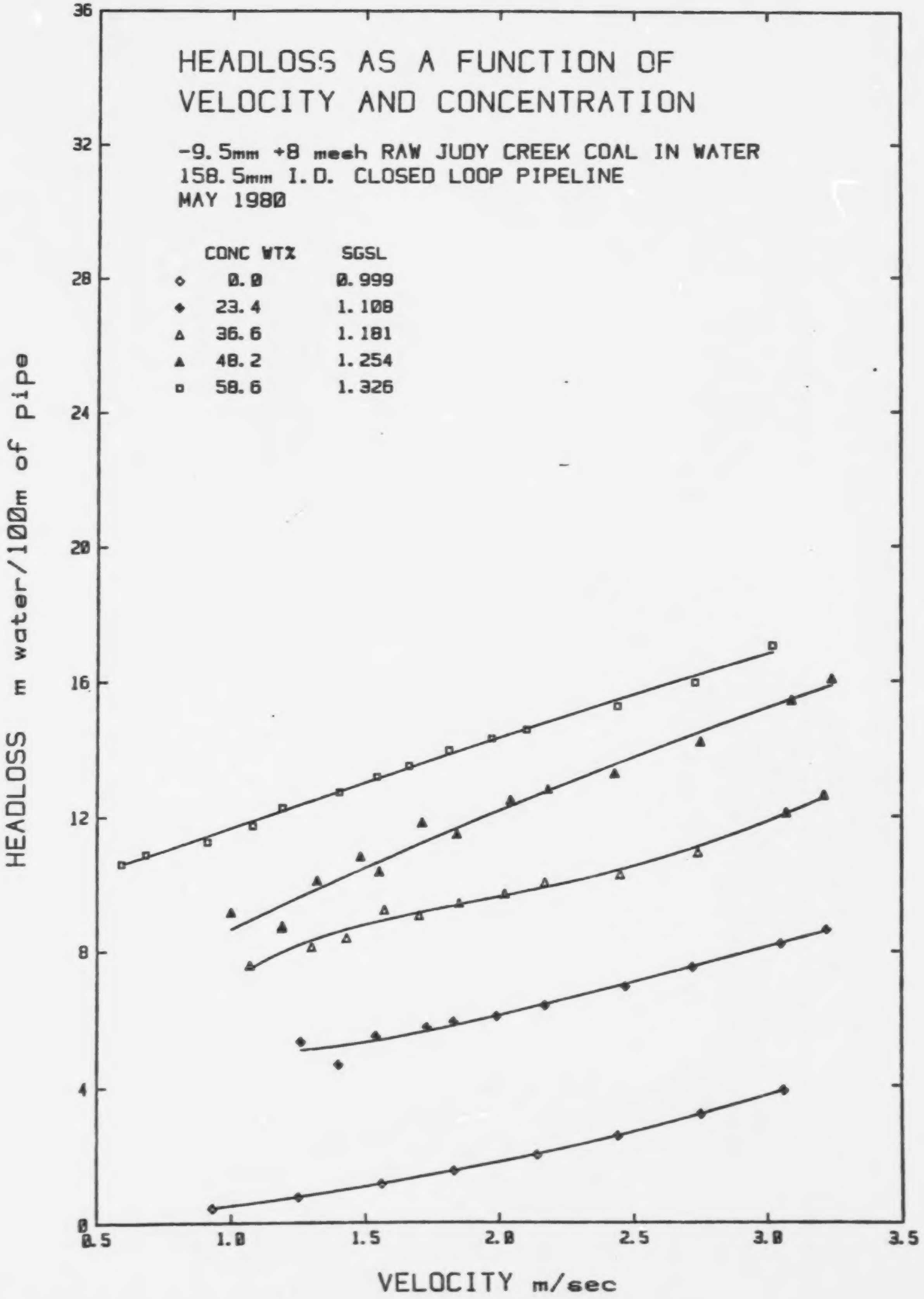

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-9.5mm +8 mesh RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 23.4 1.108
△ 36.6 1.181
▲ 48.2 1.254
□ 58.6 1.326
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
4
8
12
16
20
24
28
32
36
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 26

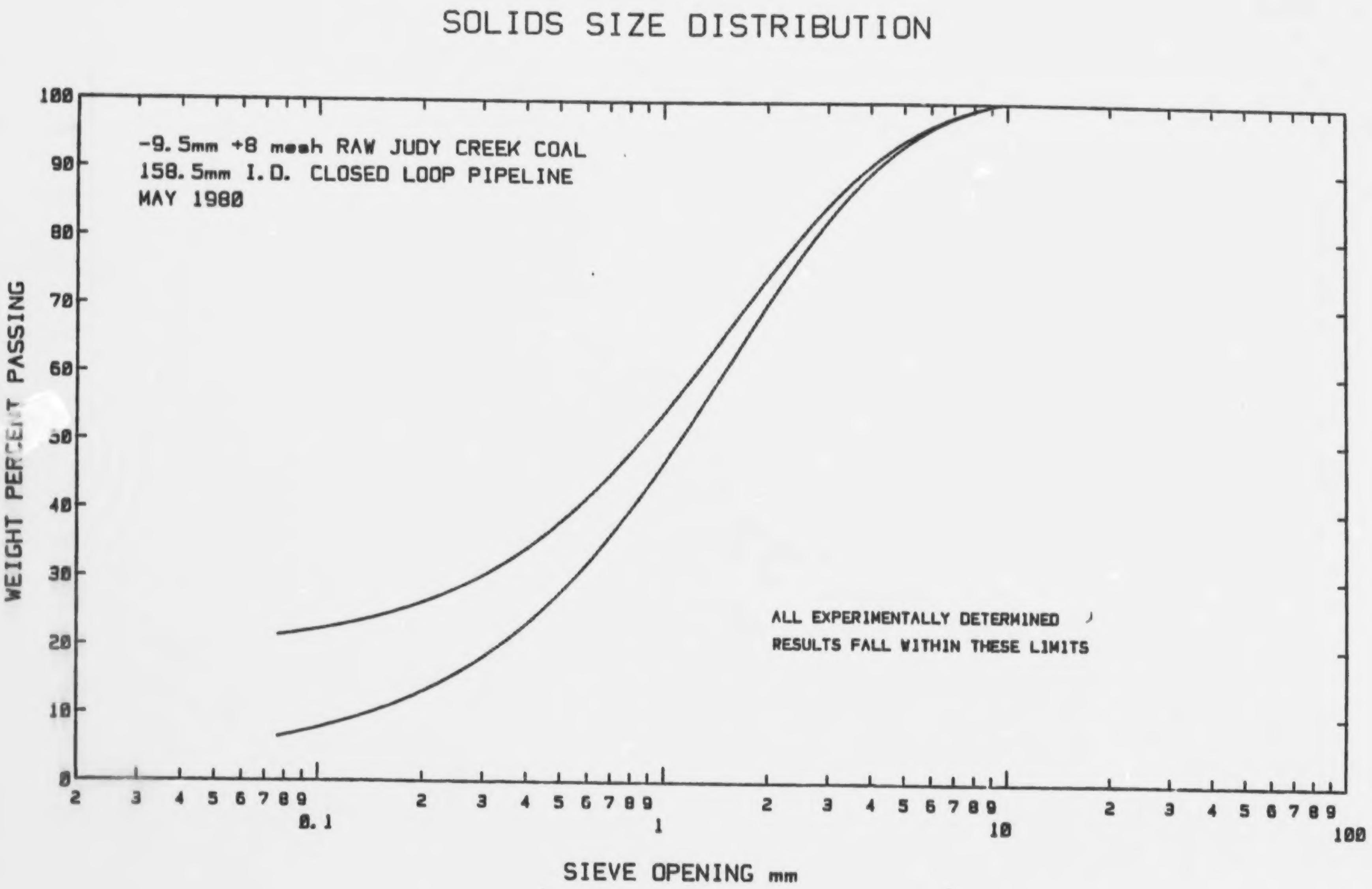

SOLIDS SIZE DISTRIBUTION
-9.5mm +8 mesh RAW JUDY CREEK COAL
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
SIEVE OPENING mm
2
3
4
5
6
7
8
9
0.1
1
10
100

Figure 27

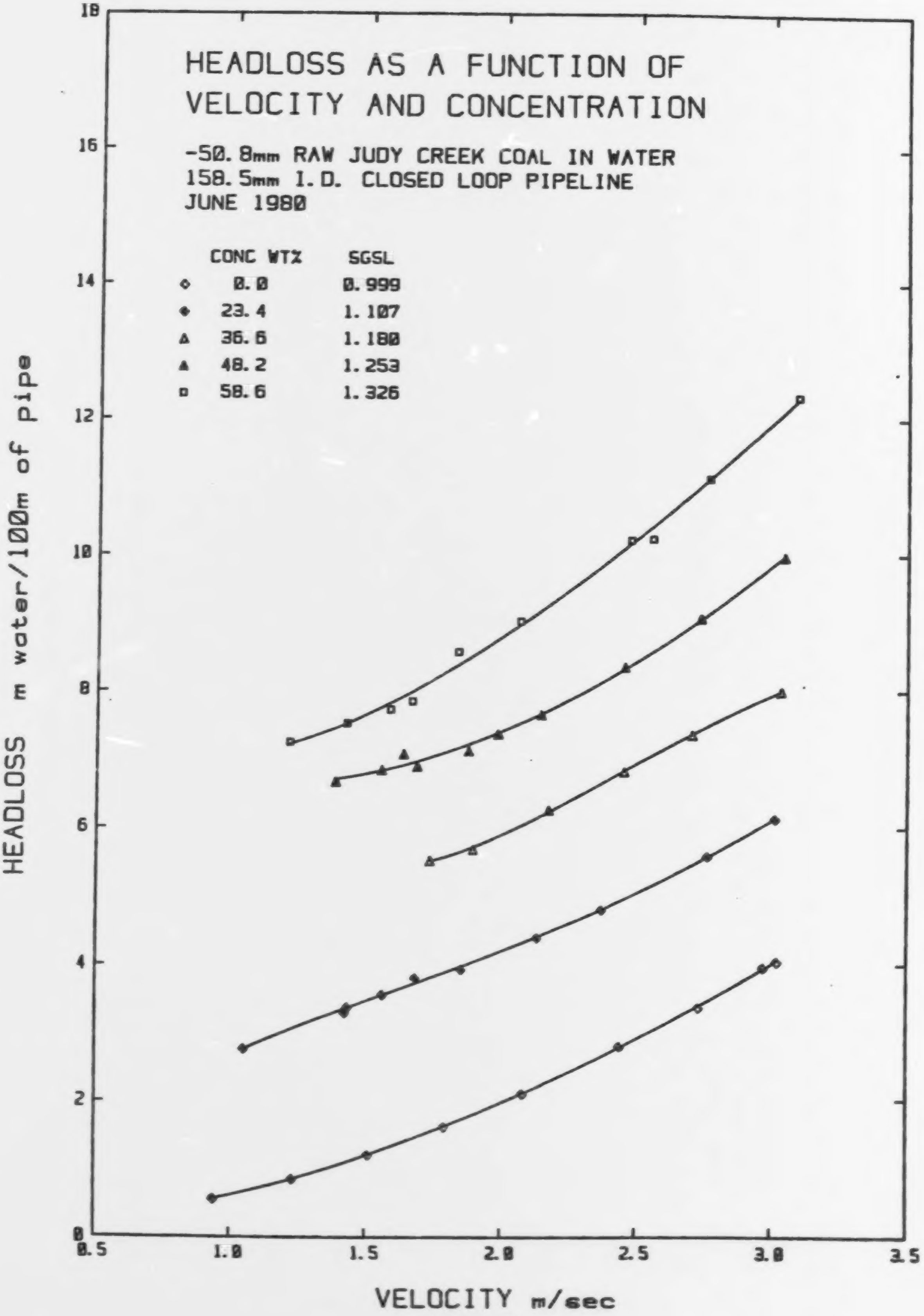

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 23.4 1.107
△ 36.6 1.180
▲ 48.2 1.253
□ 58.6 1.326
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 28

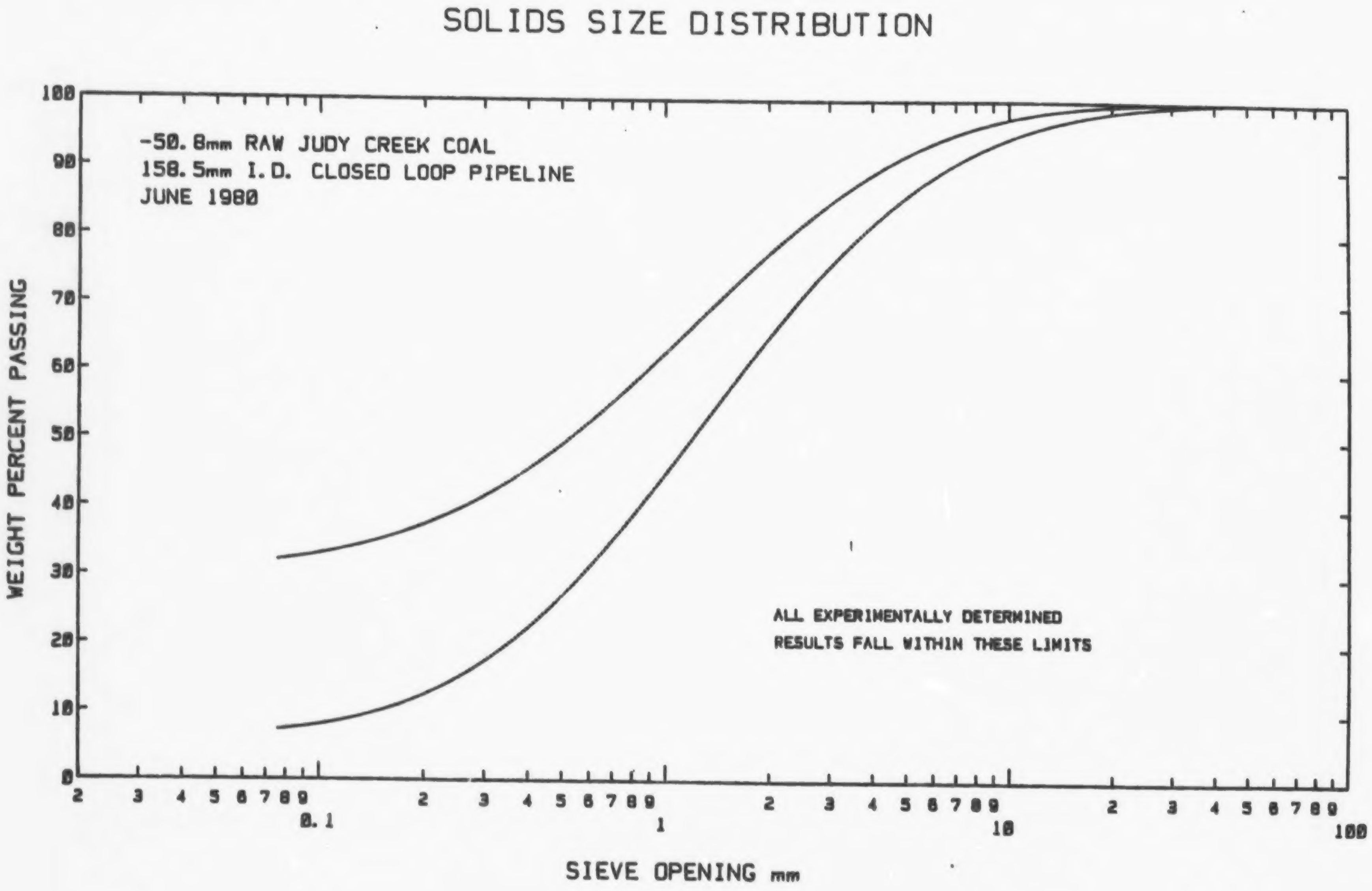

SOLIDS SIZE DISTRIBUTION
-50.8mm RAW JUDY CREEK COAL
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
2 3 4 5 6 7 8 9
0.1
2 3 4 5 6 7 8 9
1
2 3 4 5 6 7 8 9
10
2 3 4 5 6 7 8 9
100
SIEVE OPENING mm

Figure 29

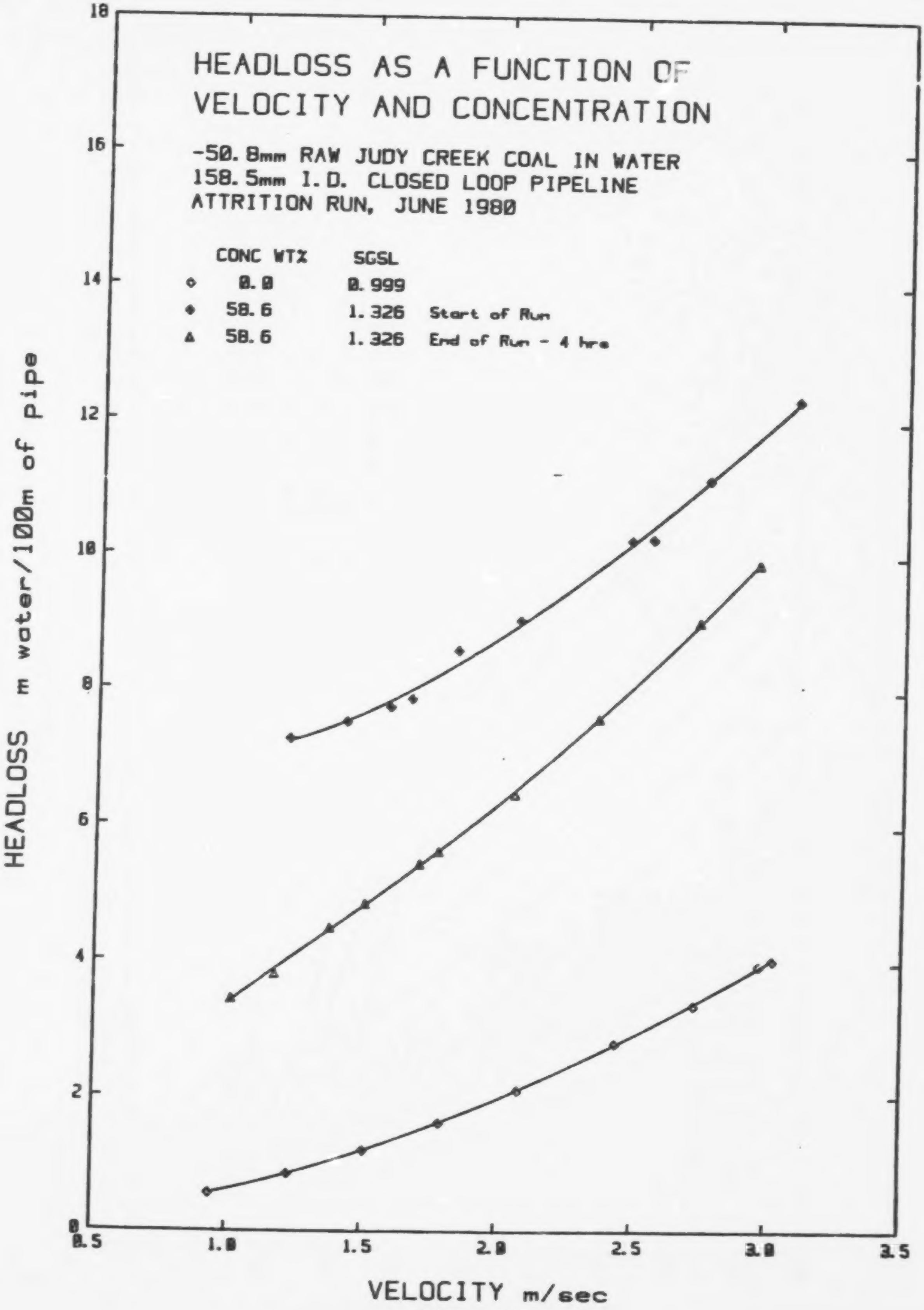

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, JUNE 1980
CONC WT% SGSL
◇ 0.0 0.999
◆ 58.6 1.326 Start of Run
△ 58.6 1.326 End of Run - 4 hrs
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 30

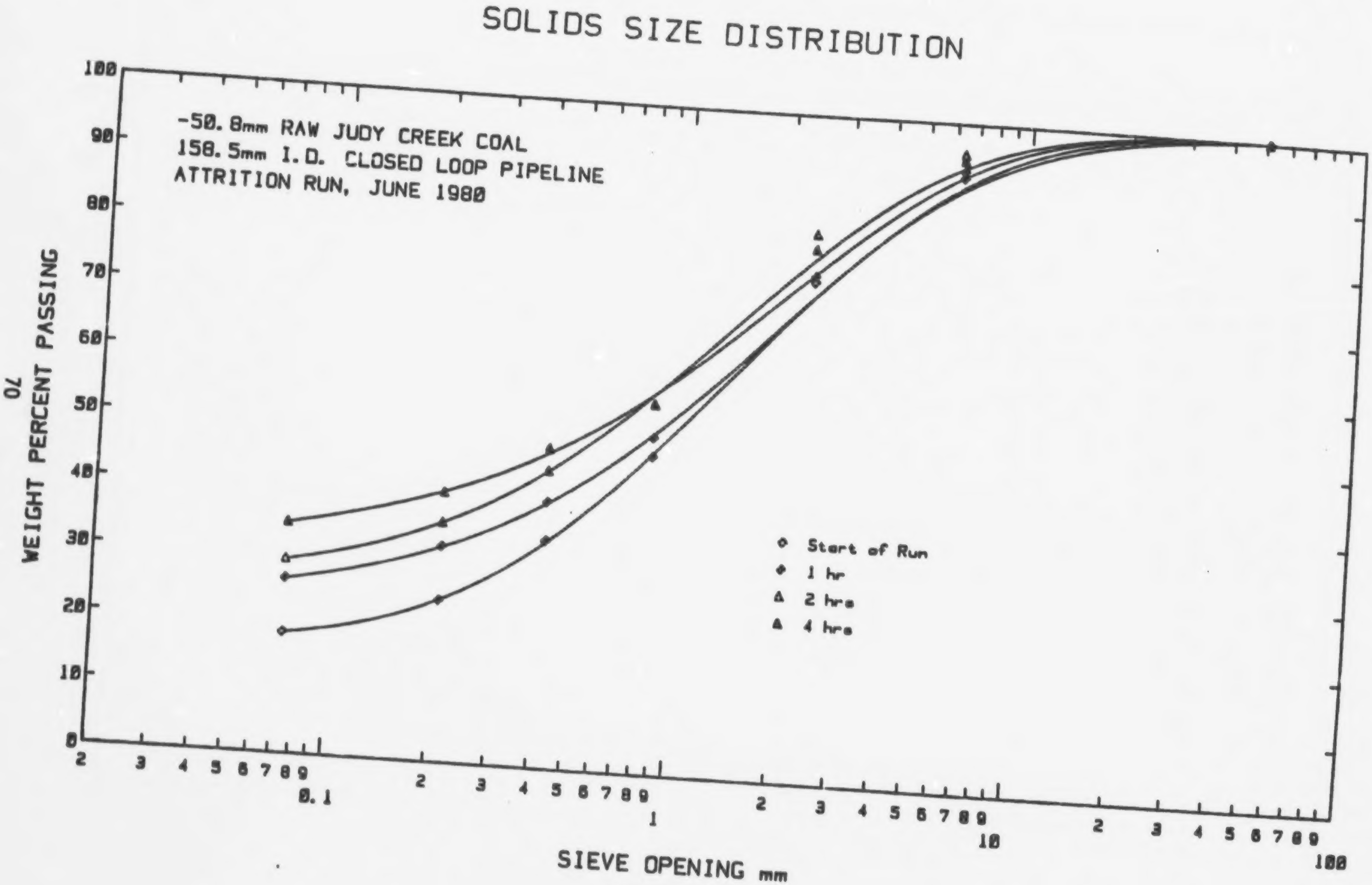

SOLIDS SIZE DISTRIBUTION
-50.8mm RAW JUDY CREEK COAL
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, JUNE 1980
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
2
3
4
5
6
7
8
9
0.1
1
10
100
SIEVE OPENING mm
◇ Start of Run
◆ 1 hr
△ 2 hrs
▲ 4 hrs

Figure 31

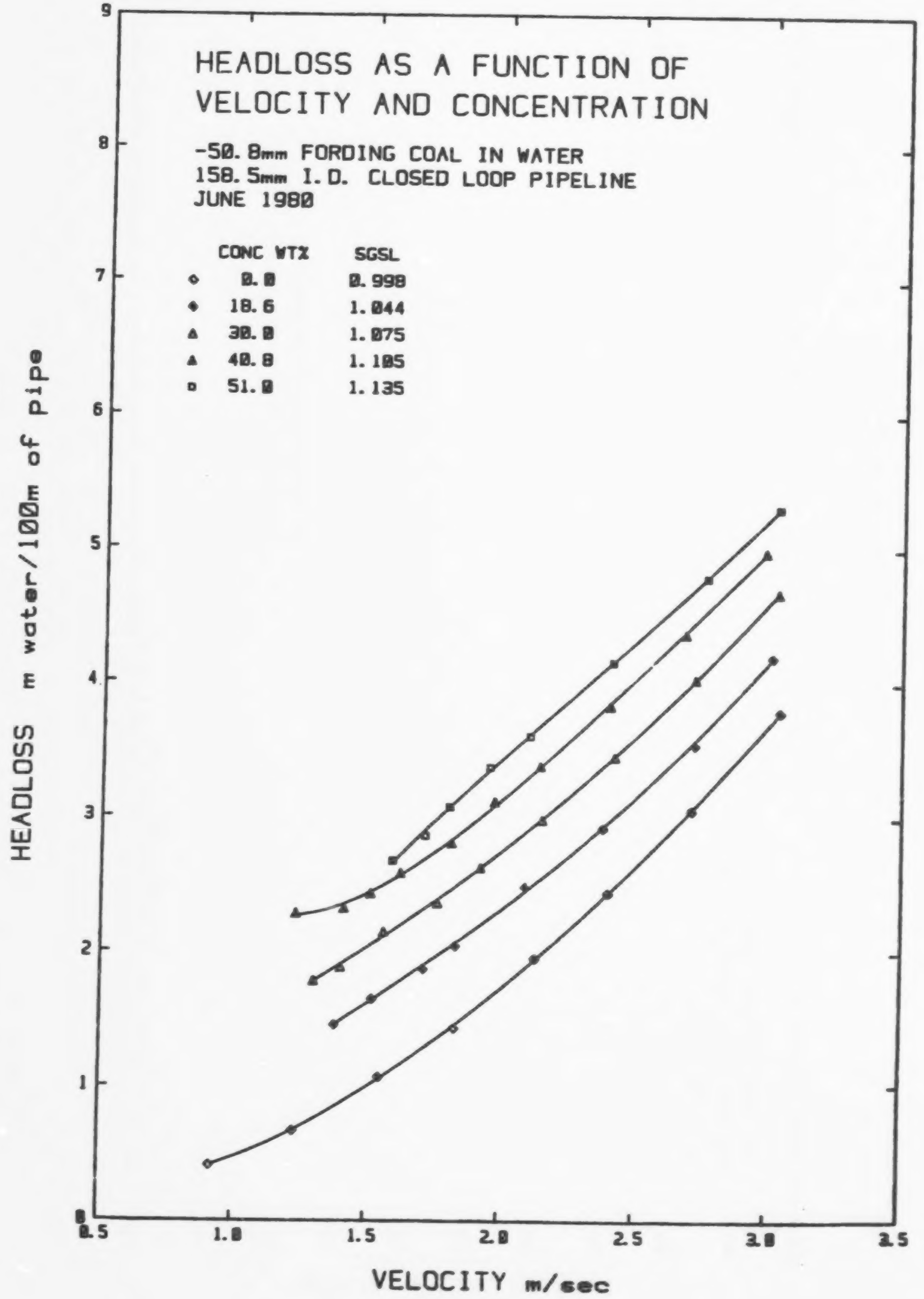

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980
CONC WT%
SGSL
◇ 0.0 0.998
◆ 18.6 1.044
△ 30.0 1.075
▲ 40.8 1.105
□ 51.0 1.135
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 32

SOLIDS SIZE DISTRIBUTION

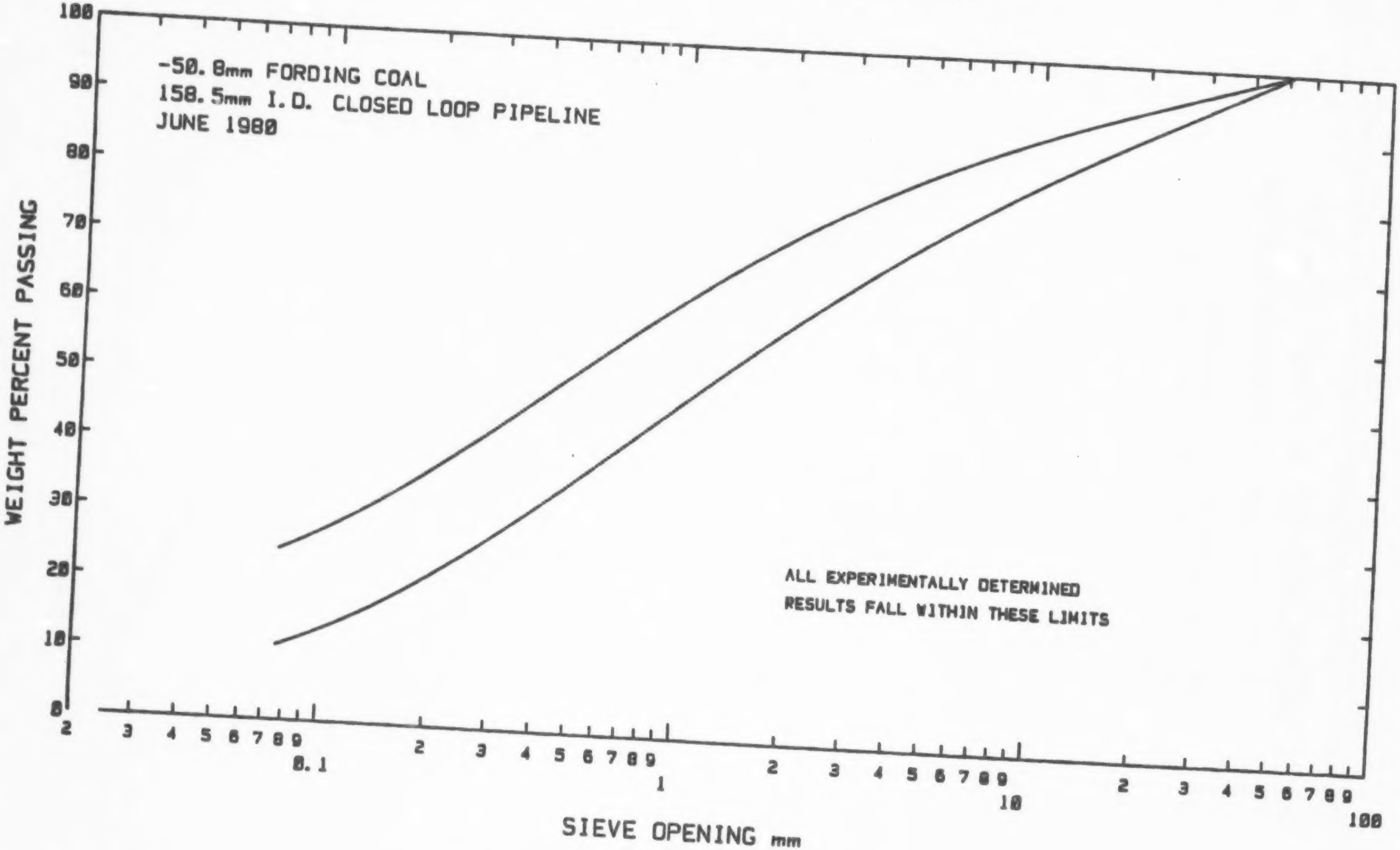


Figure 33

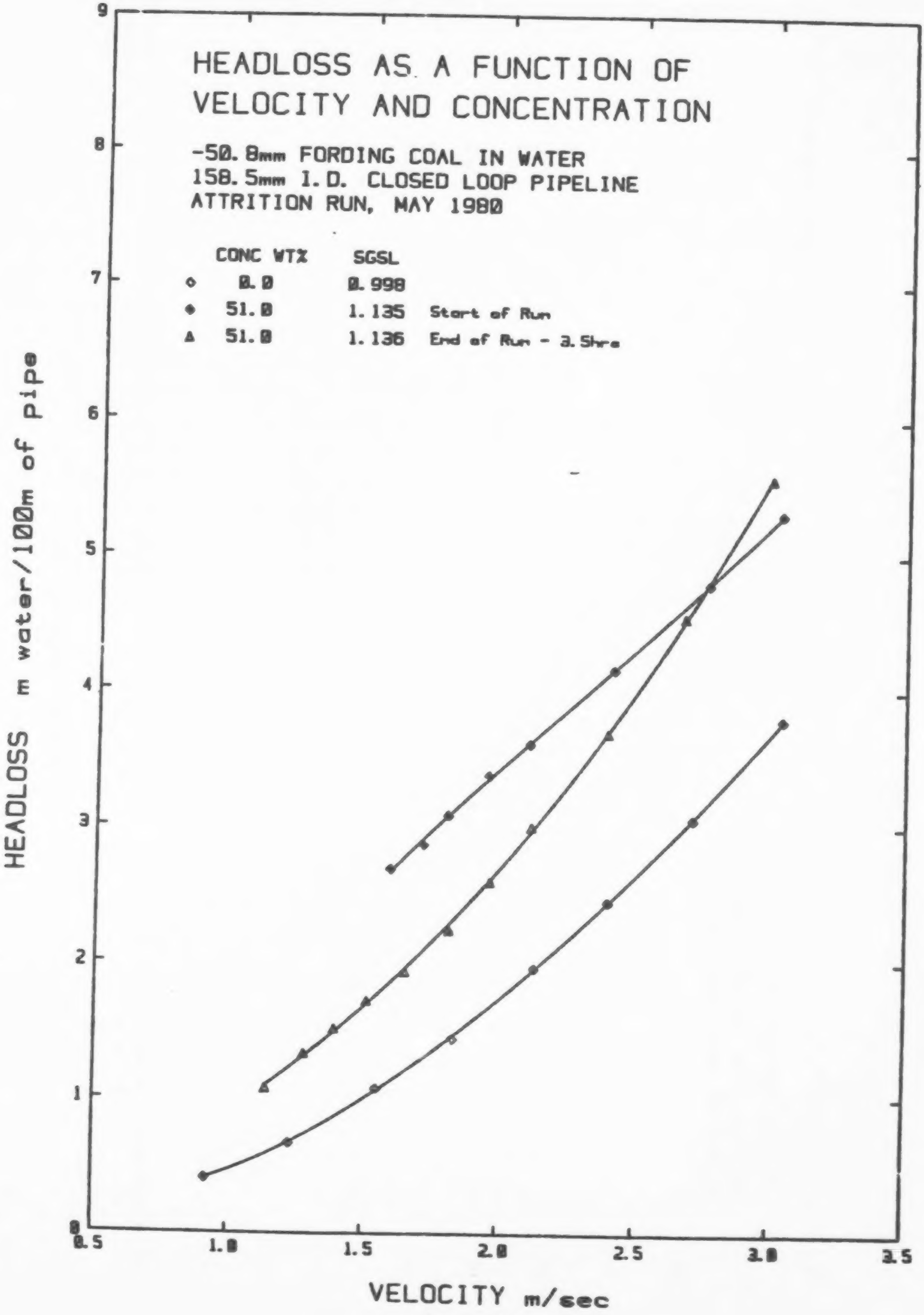

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MAY 1980
CONC WT%
SGSL
○ 0.0 0.998
◆ 51.0 1.135 Start of Run
▲ 51.0 1.136 End of Run - 3.5hrs
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 34

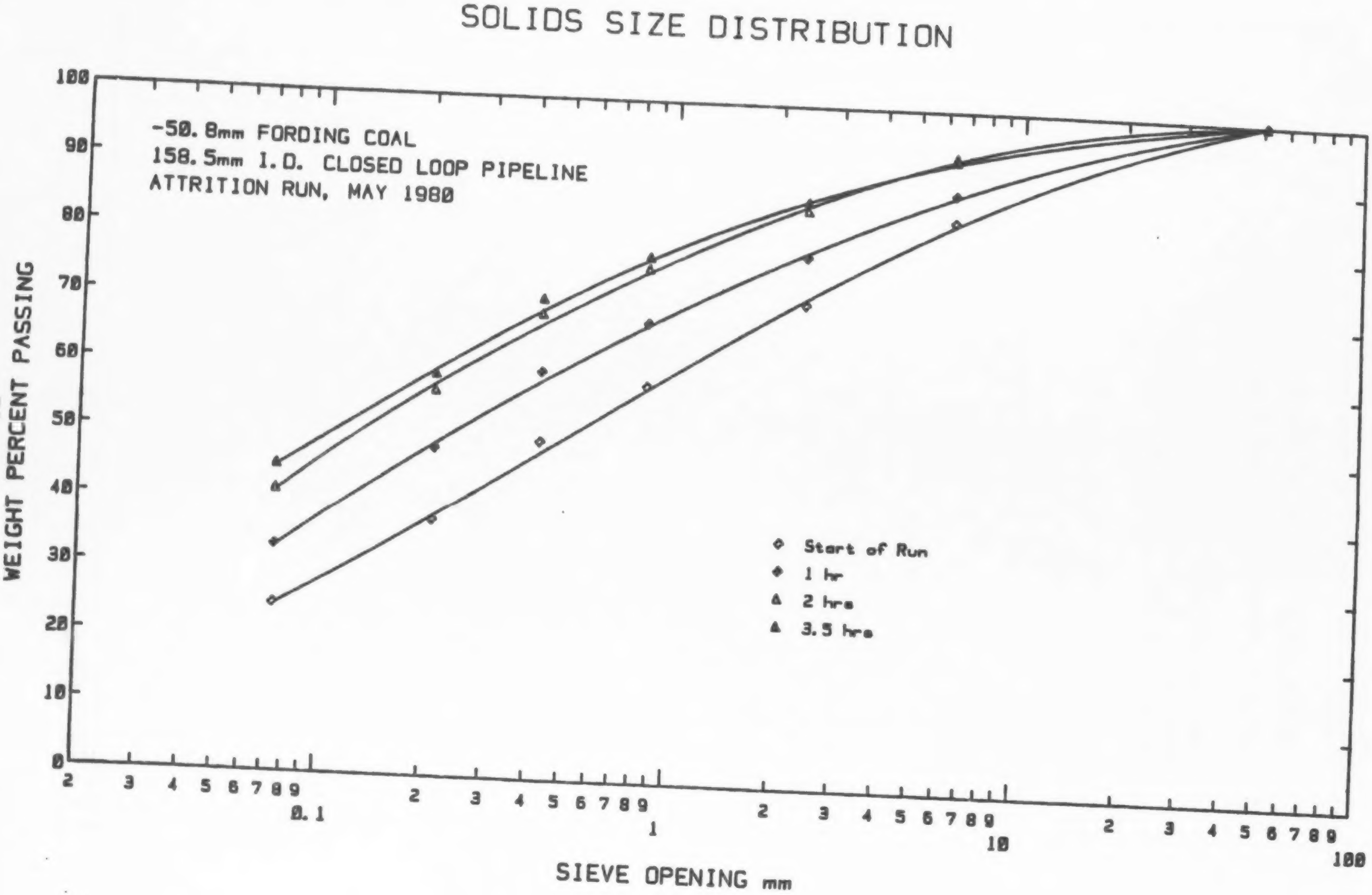

SOLIDS SIZE DISTRIBUTION
-50.8mm FORDING COAL
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MAY 1980
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
2 3 4 5 6 7 8 9
0.1
2 3 4 5 6 7 8 9
1
2 3 4 5 6 7 8 9
10
2 3 4 5 6 7 8 9
100
SIEVE OPENING mm
◇ Start of Run
◆ 1 hr
△ 2 hrs
▲ 3.5 hrs

Figure 35

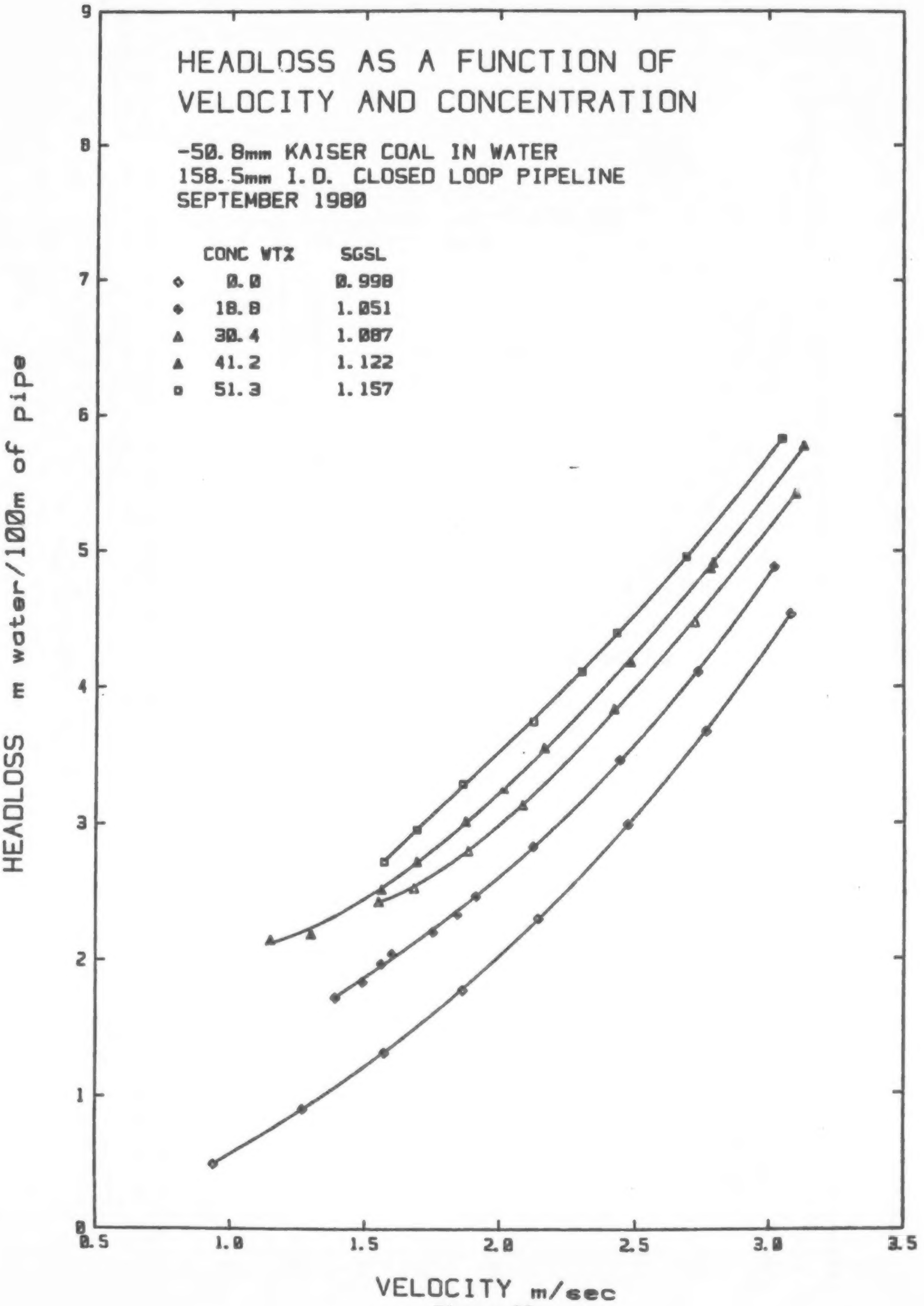

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
SEPTEMBER 1980
CONC WT%
SGSL
◇ 0.0 0.998
◆ 18.8 1.051
△ 30.4 1.087
▲ 41.2 1.122
□ 51.3 1.157
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 36

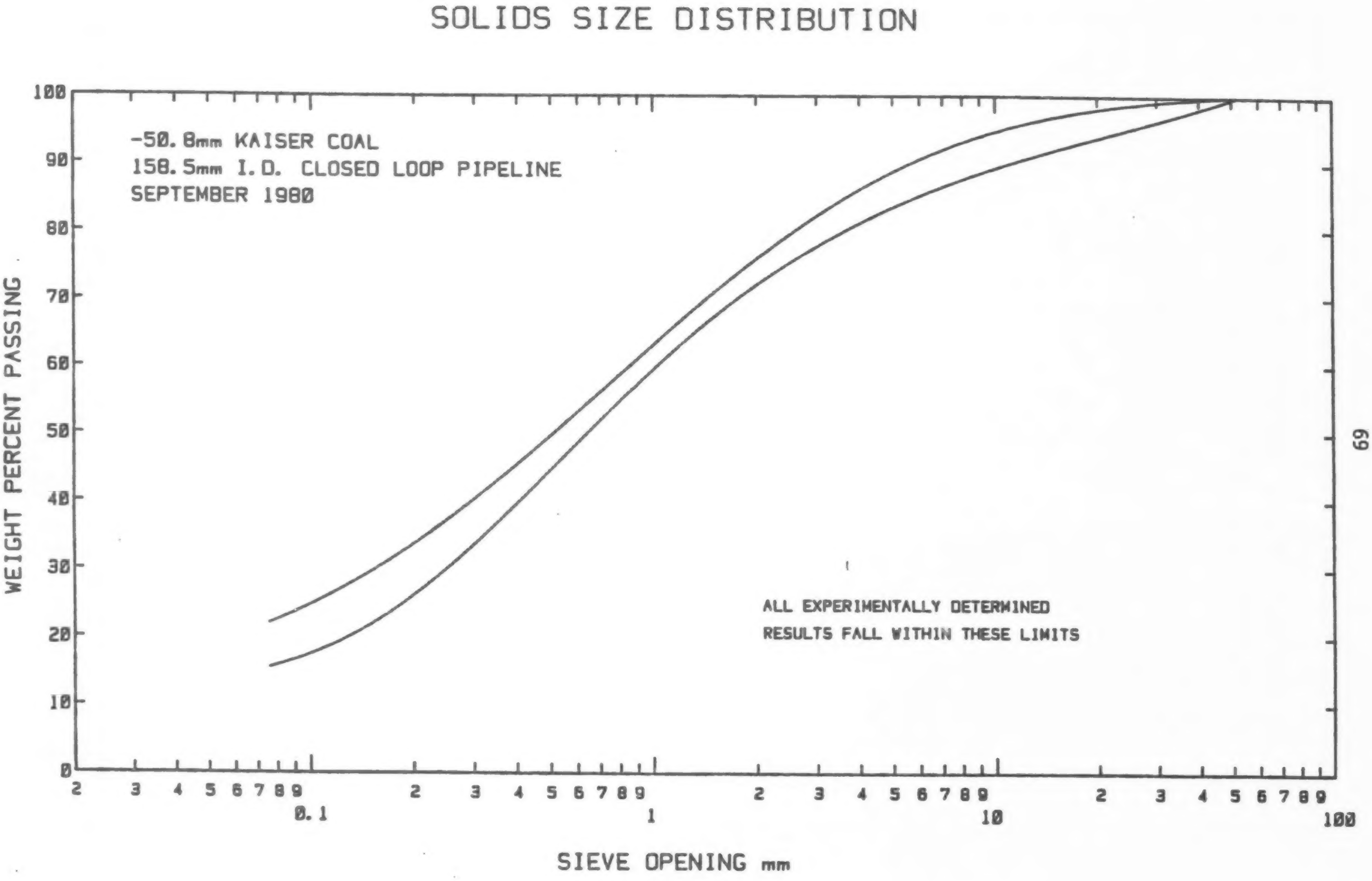

SOLIDS SIZE DISTRIBUTION
-50.8mm KAISER COAL
158.5mm I.D. CLOSED LOOP PIPELINE
SEPTEMBER 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
2
3
4
5
6
7
8
9
0.1
1
10
100
SIEVE OPENING mm

Figure 37

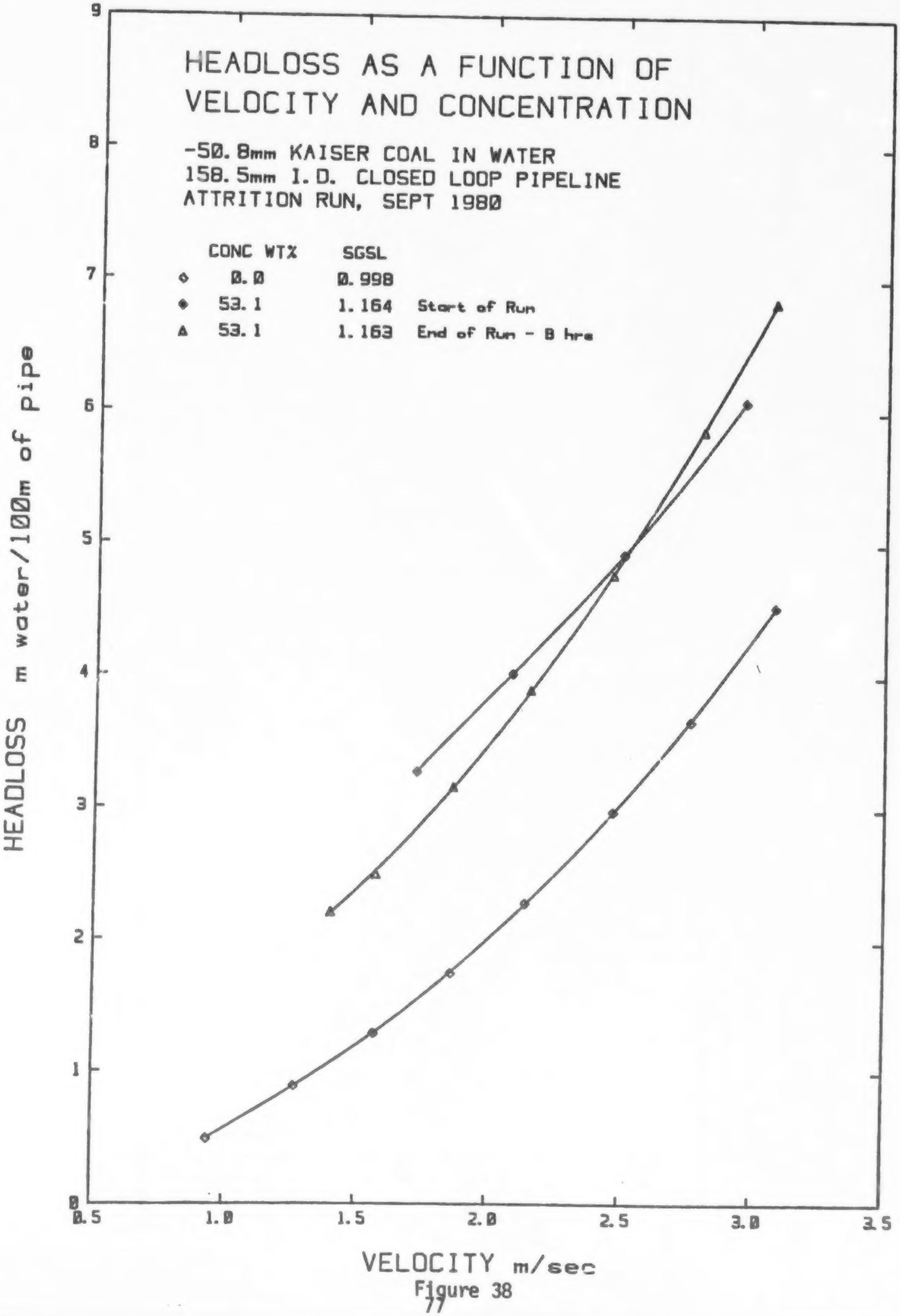

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
CONC WT% SGSL
◇ 0.0 0.998
◆ 53.1 1.164 Start of Run
△ 53.1 1.163 End of Run - 8 hrs
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 38

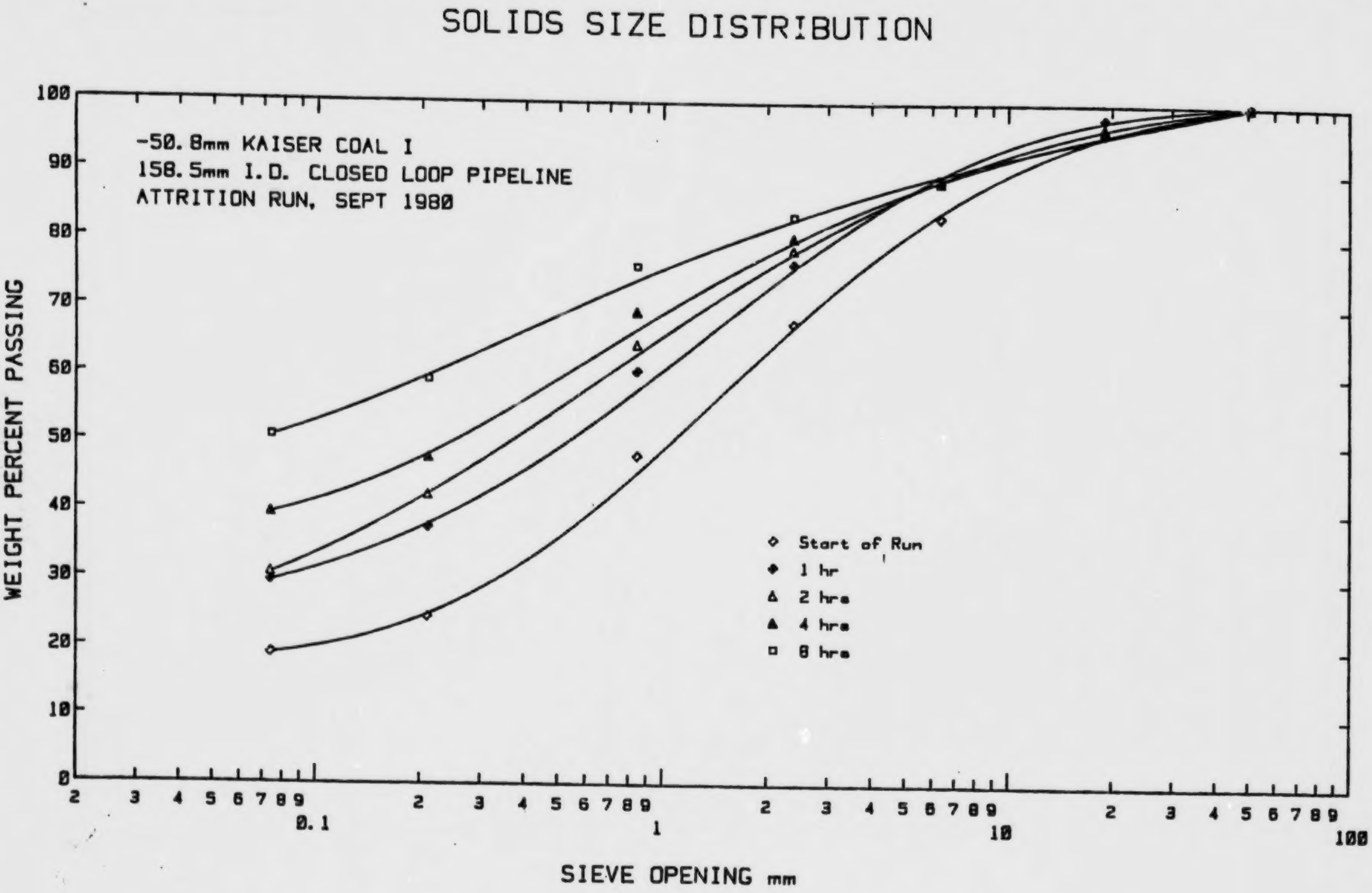

SOLIDS SIZE DISTRIBUTION
-50.8mm KAISER COAL I
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
◇ Start of Run
◆ 1 hr
△ 2 hrs
▲ 4 hrs
□ 8 hrs
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
SIEVE OPENING mm
2
3
4
5
6
7
8
9
0.1
1
10
100

Figure 39

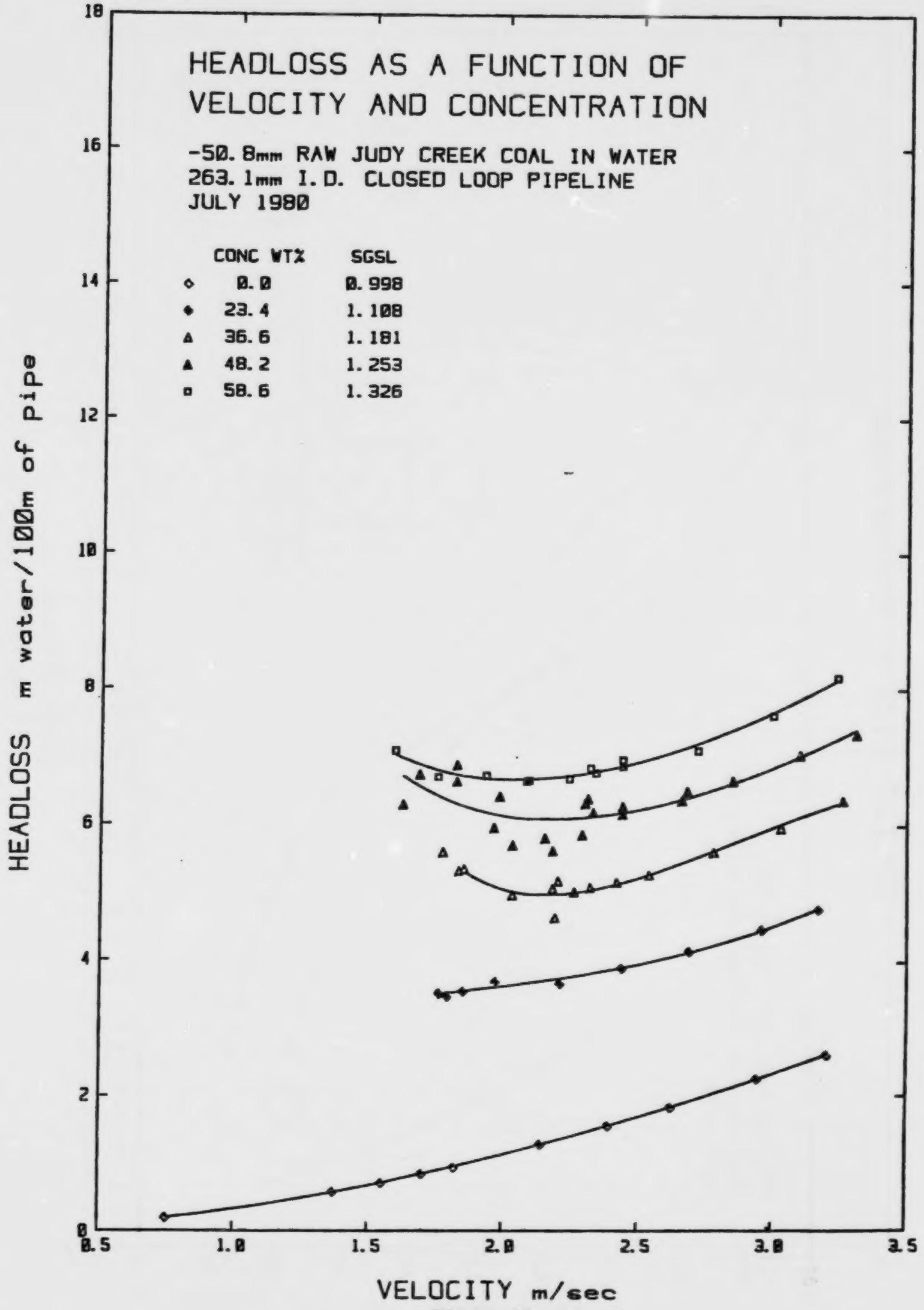

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980
CONC WT% SGSL
◇ 0.0 0.998
◆ 23.4 1.108
△ 36.6 1.181
▲ 48.2 1.253
□ 58.6 1.326
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
2
4
6
8
10
12
14
16
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 40

SOLIDS SIZE DISTRIBUTION

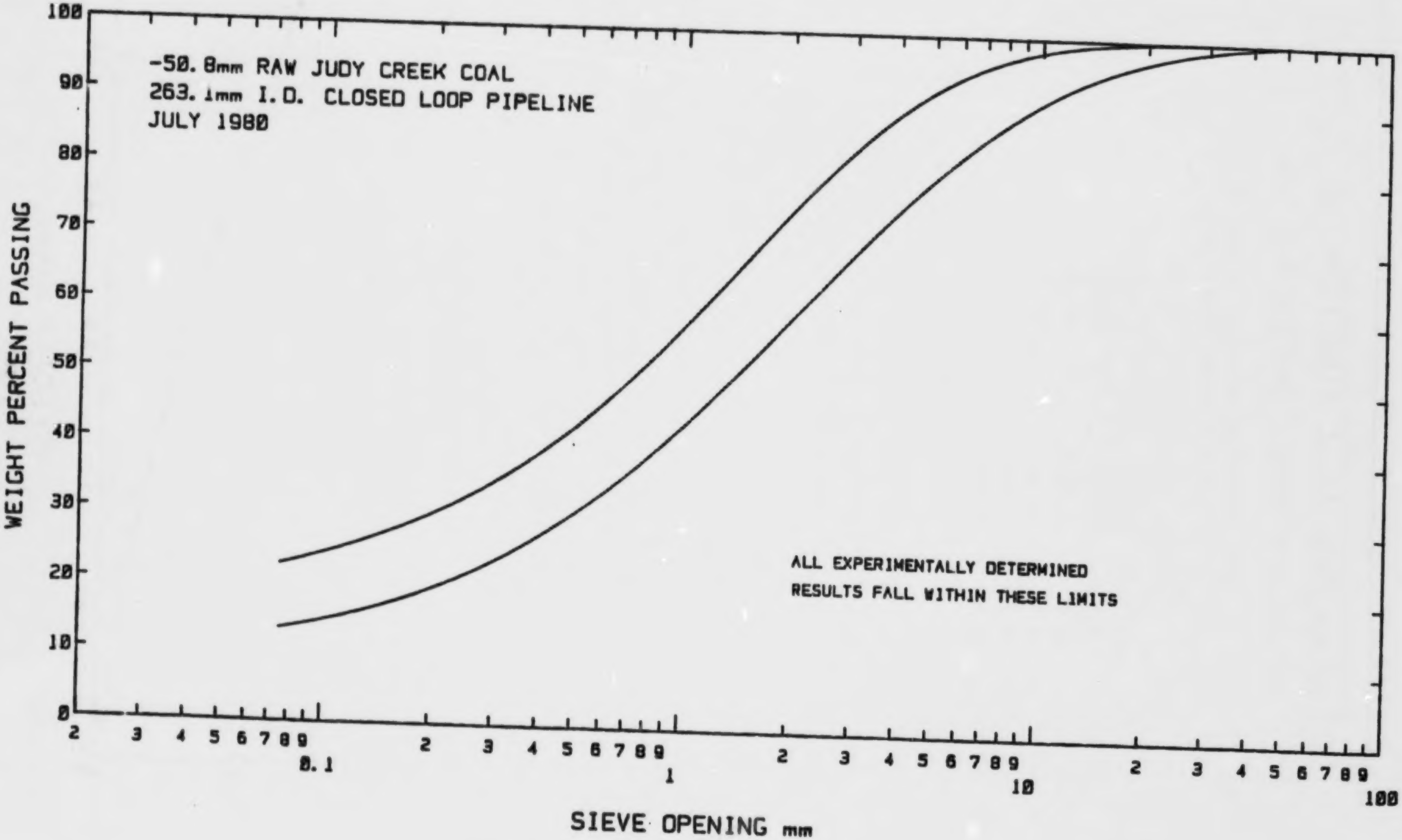


Figure 41

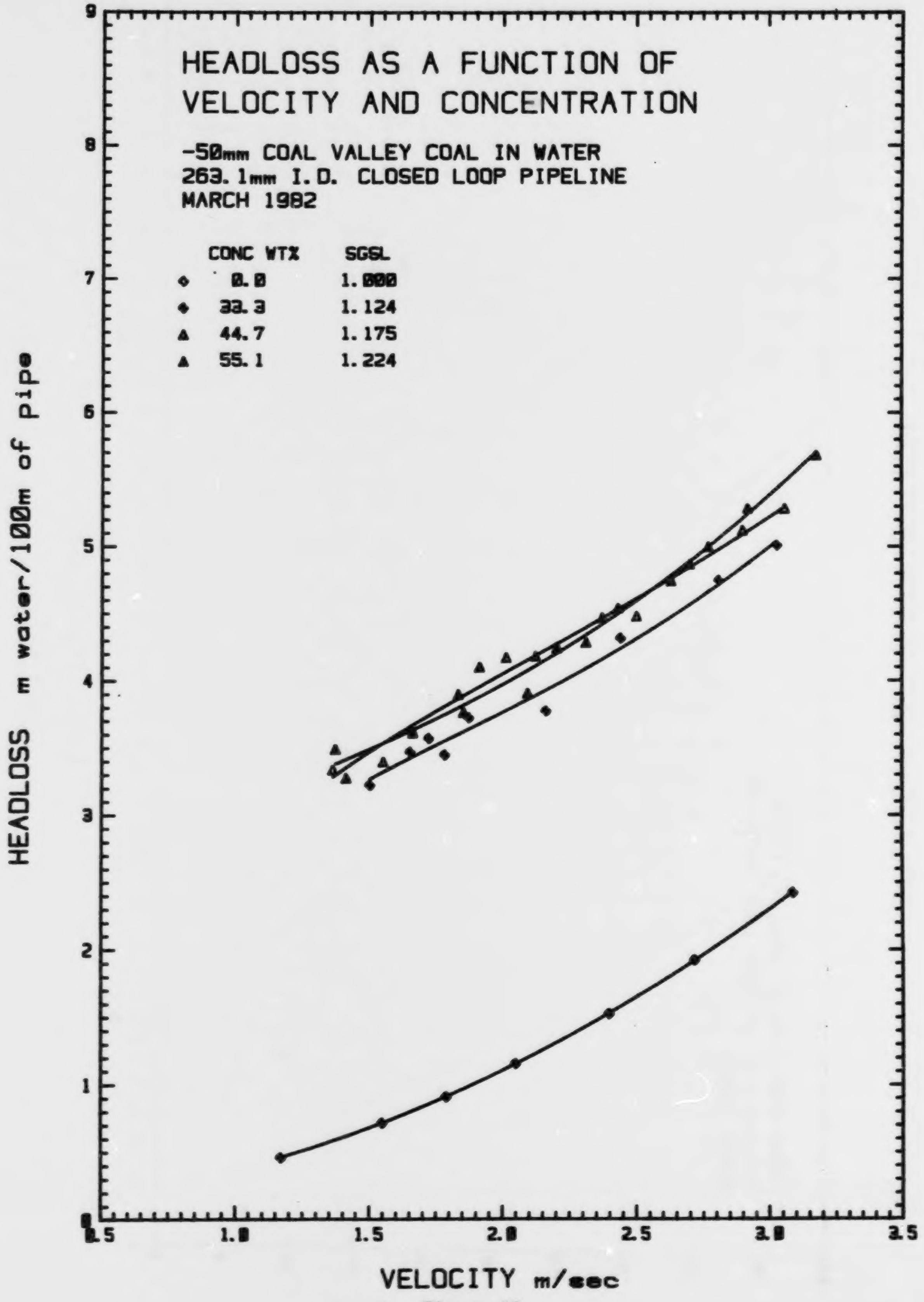

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
MARCH 1982
CONC WT%
SGSL
◇ 0.0 1.000
◆ 33.3 1.124
△ 44.7 1.175
▲ 55.1 1.224
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 42

SOLIDS SIZE DISTRIBUTION

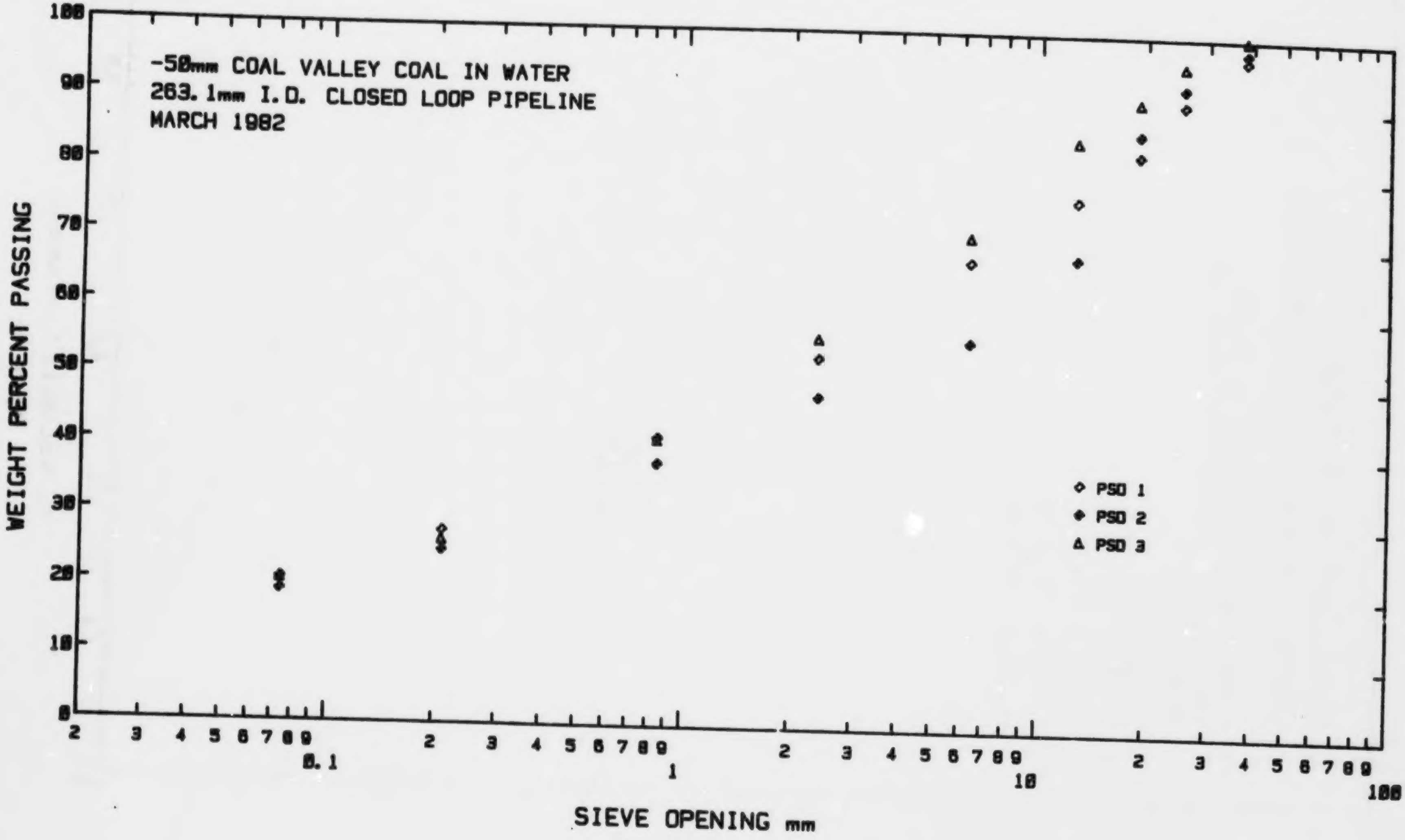


Figure 43

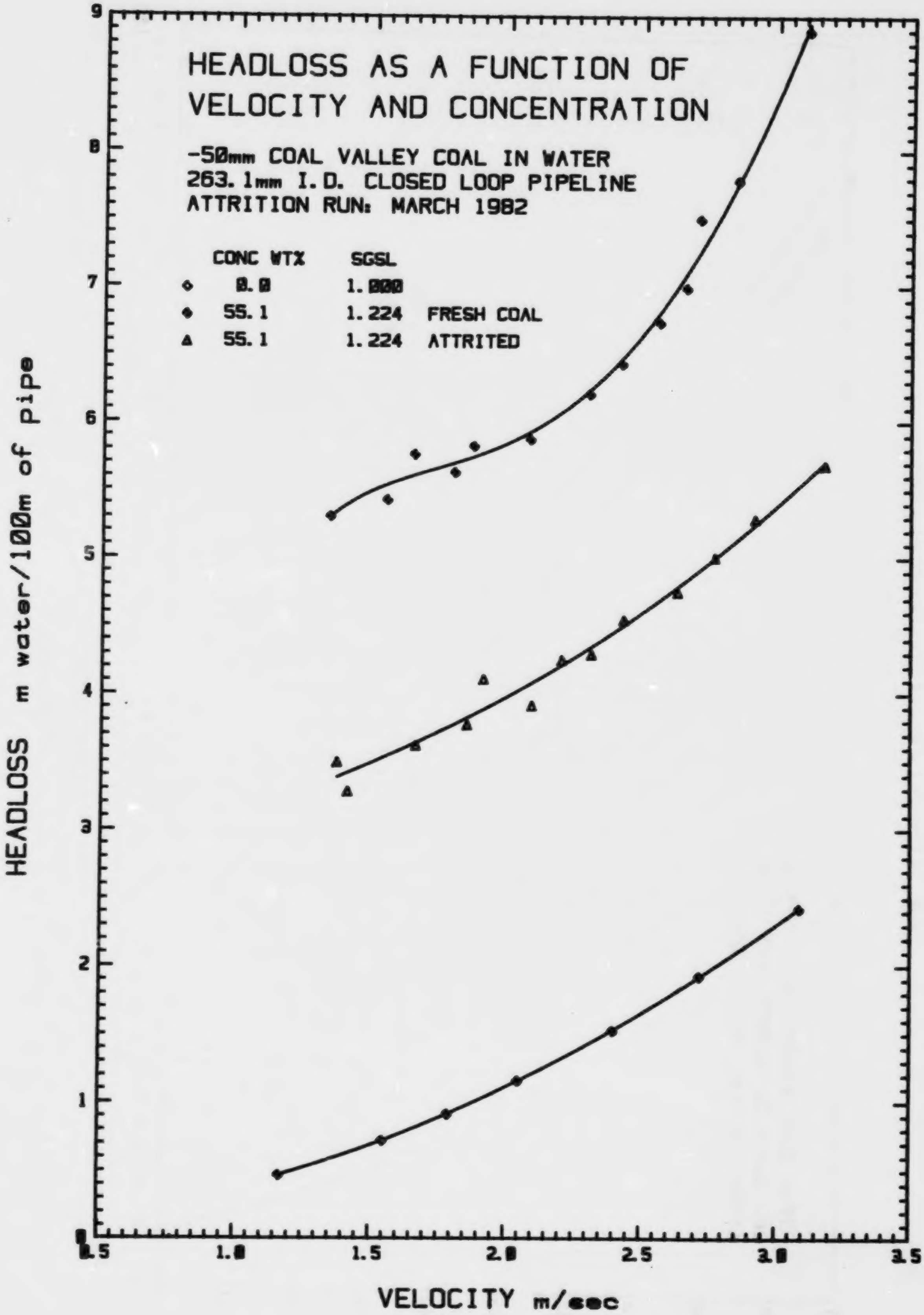

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN: MARCH 1982
CONC WT%
SGSL
◇ 0.0 1.000
◆ 55.1 1.224 FRESH COAL
△ 55.1 1.224 ATTRITED
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Figure 44

SOLIDS SIZE DISTRIBUTION

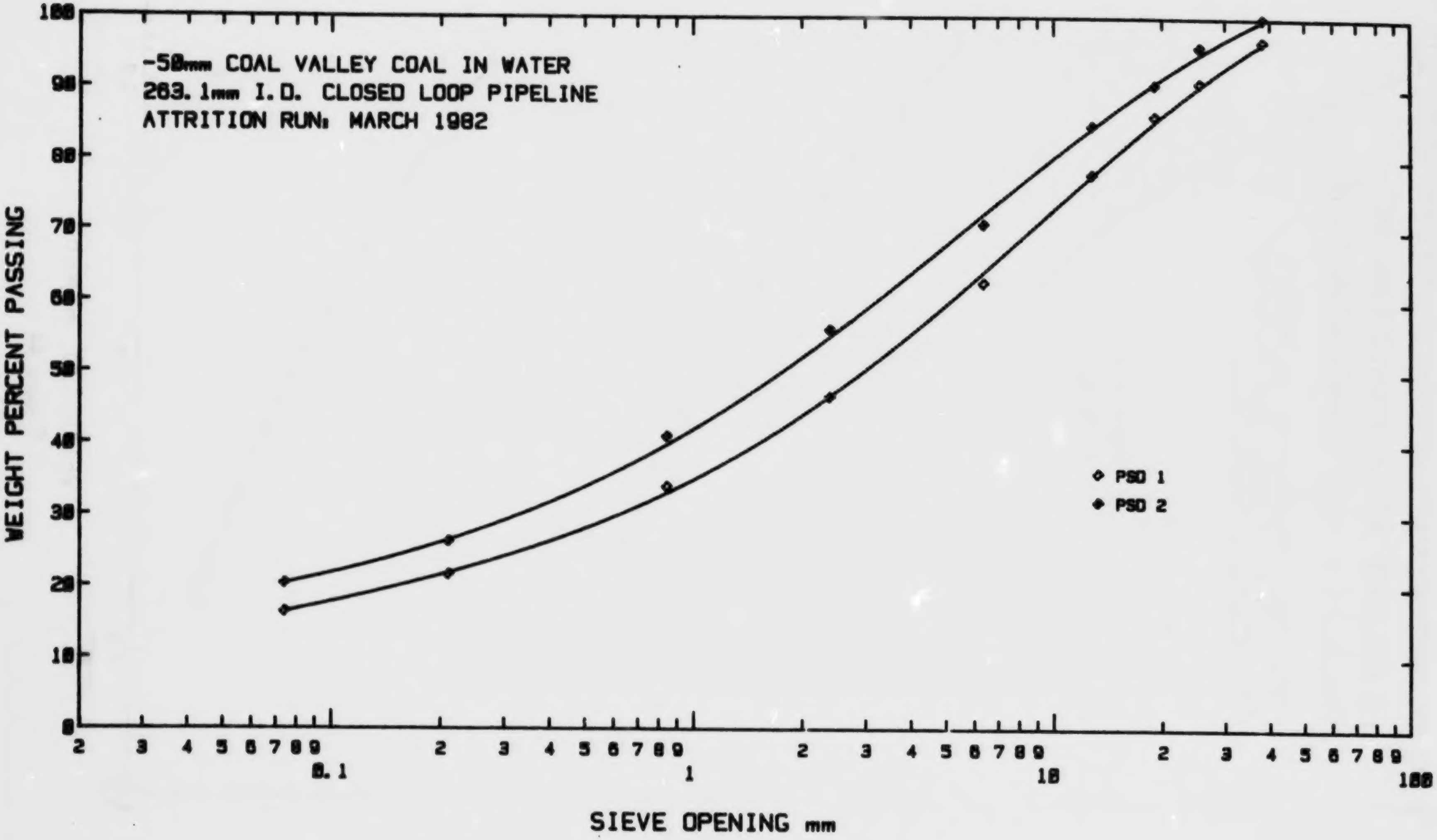


Figure 45

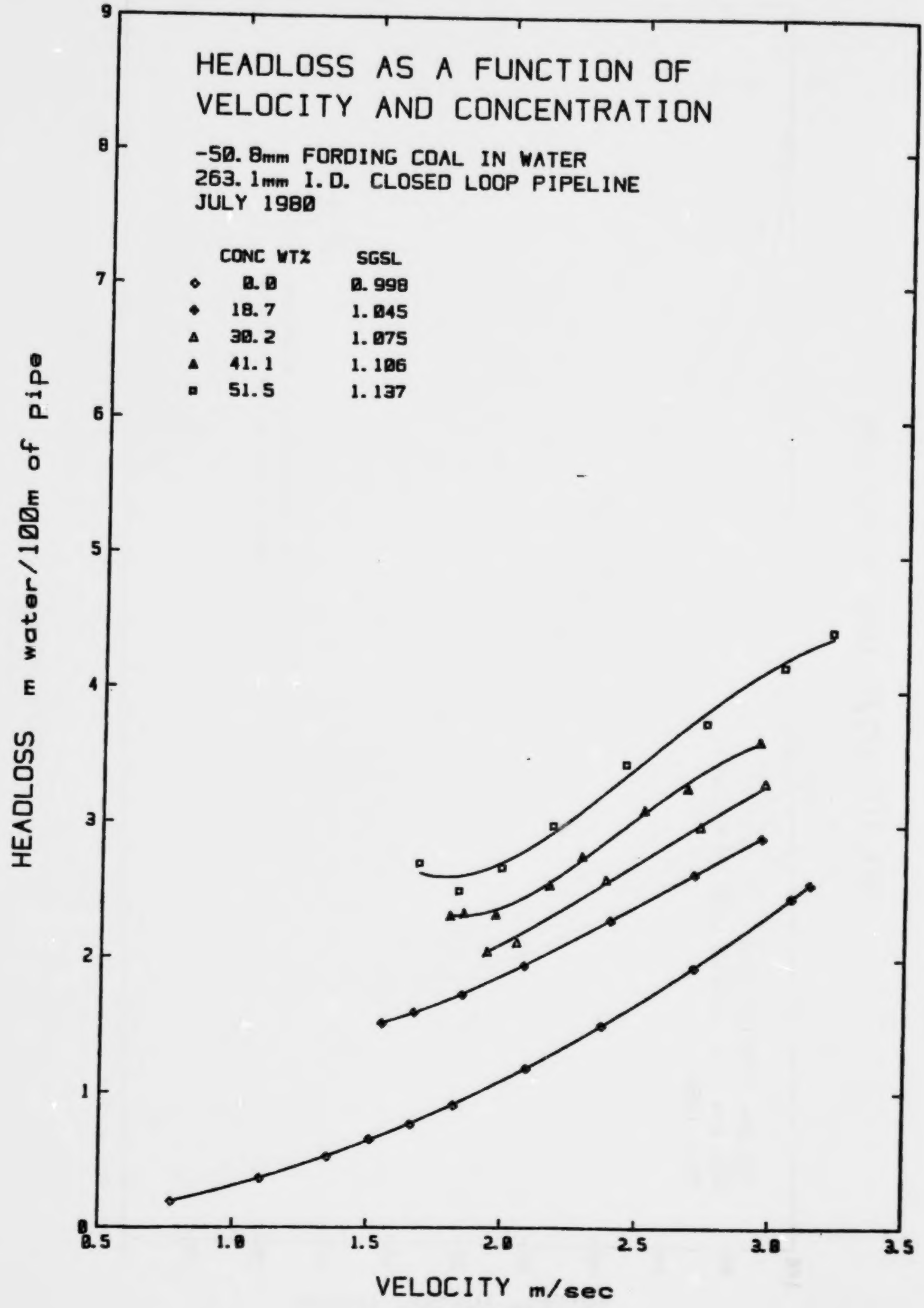

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980
CONC WT%
SGSL
◇ 0.0
0.998
◆ 18.7
1.045
△ 30.2
1.075
▲ 41.1
1.106
□ 51.5
1.137
HEADLOSS m water/100m of pipe
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 46

SOLIDS SIZE DISTRIBUTION

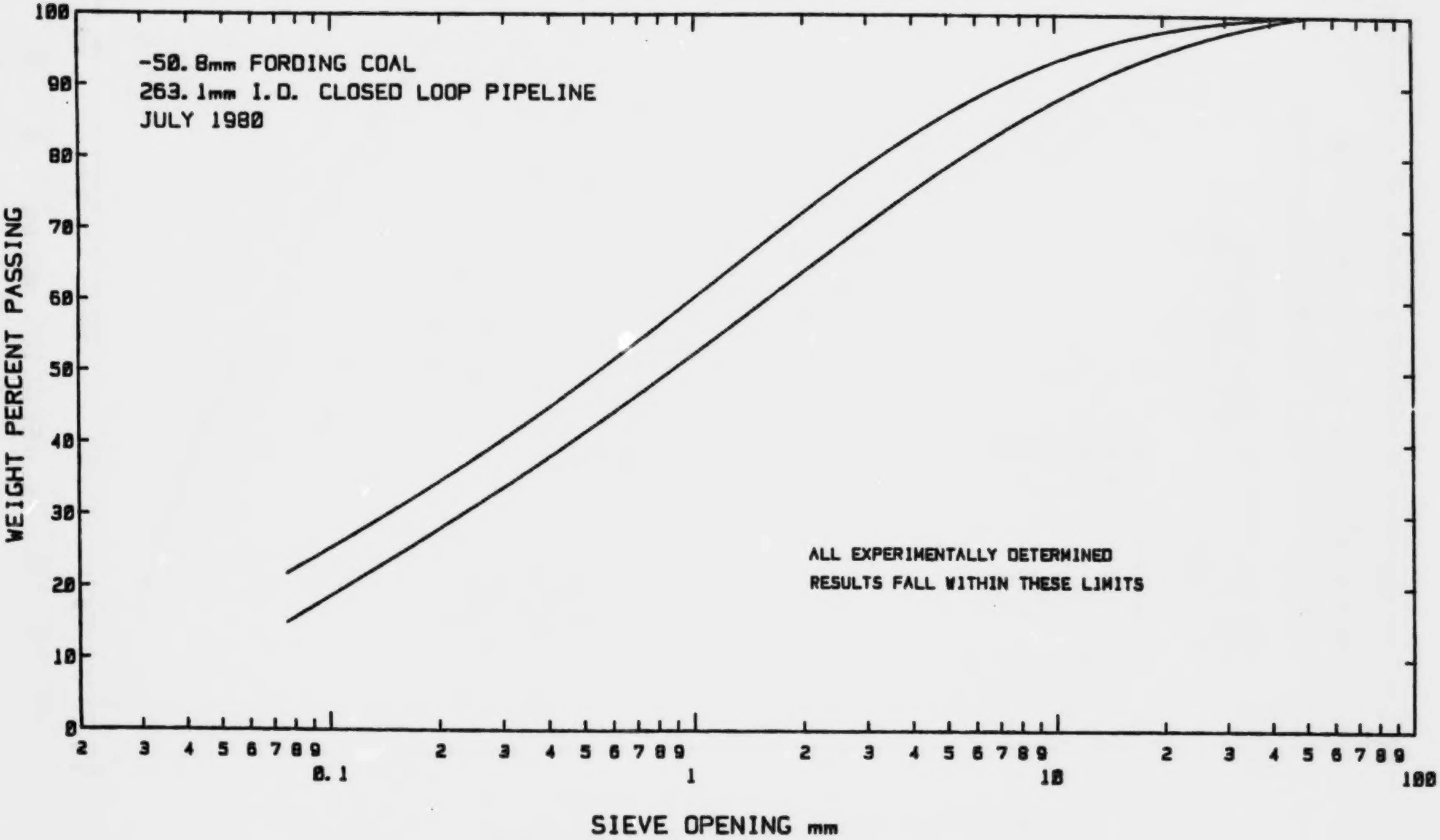


Figure 47

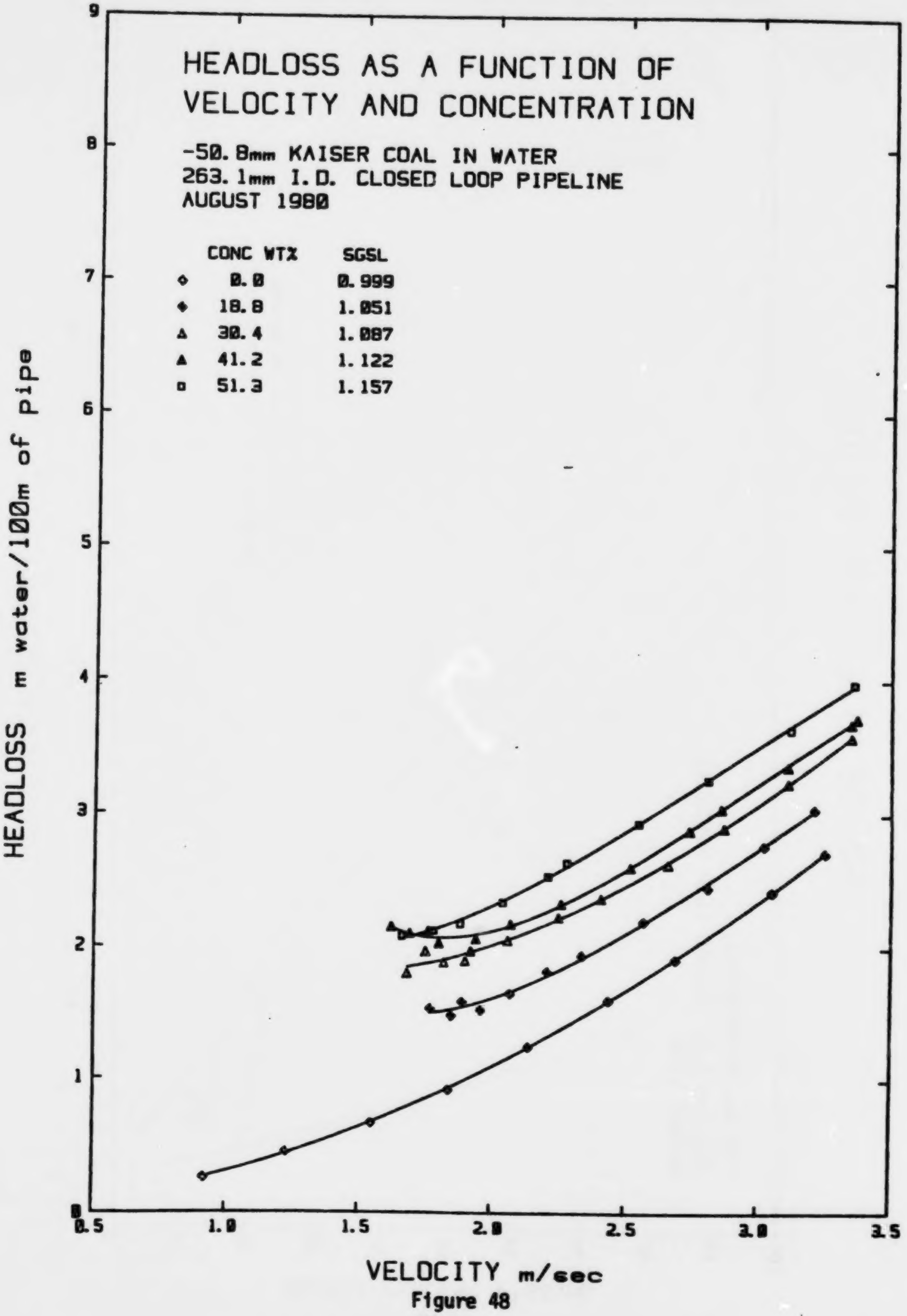
HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
CONC WT%
SGSL
◇ 0.0 0.999
◆ 18.8 1.051
△ 30.4 1.087
▲ 41.2 1.122
□ 51.3 1.157
HEADLOSS m water/100m of pipe
0
1
2
3
4
5
6
7
8
9
0.5
1.0
1.5
2.0
2.5
3.0
3.5
VELOCITY m/sec

Figure 48

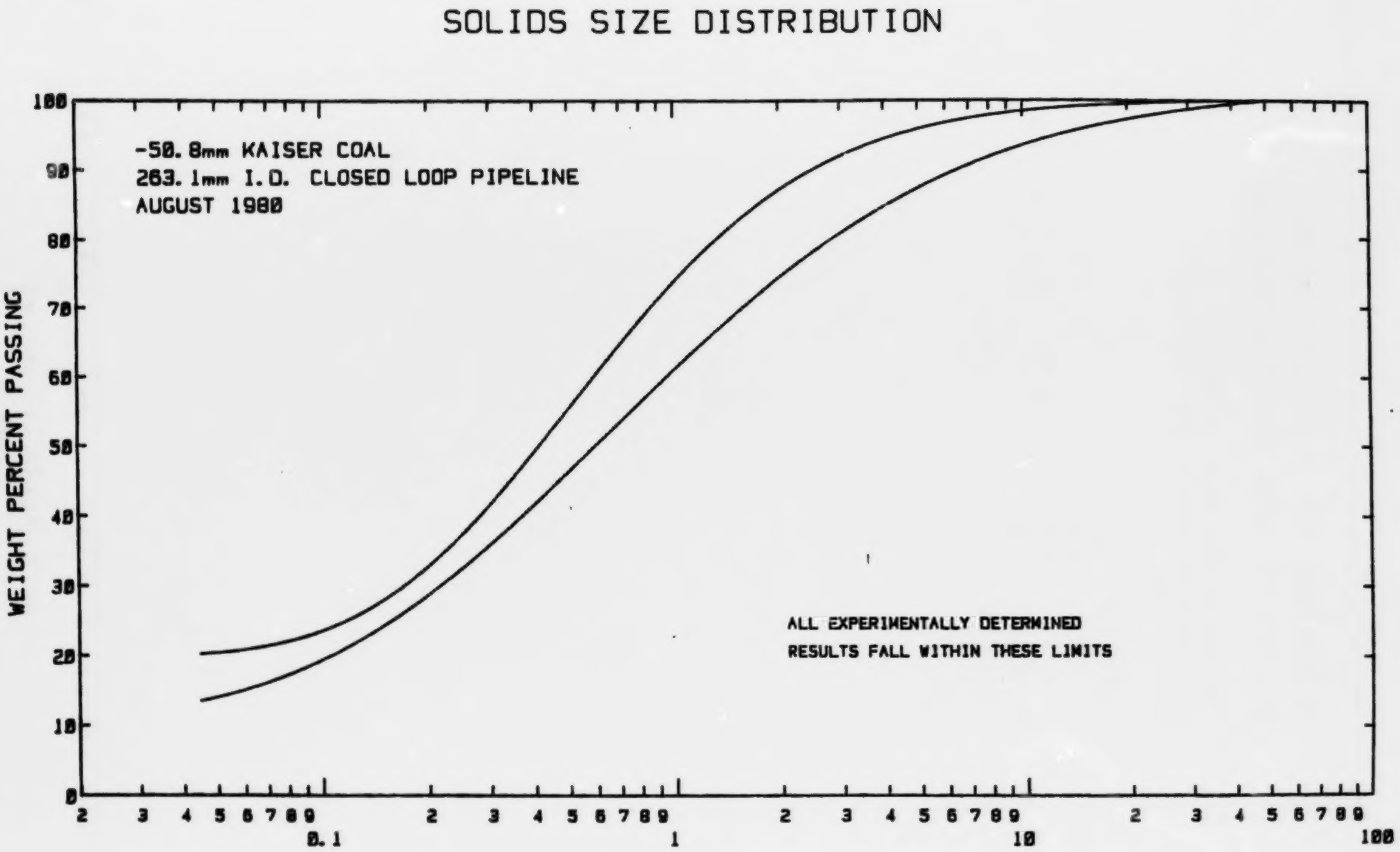

SOLIDS SIZE DISTRIBUTION
-50.8mm KAISER COAL
263.1mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
2
3
4
5
6
7
8
9
0.1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
2
3
4
5
6
7
8
9
100
SIEVE OPENING mm

Figure 49

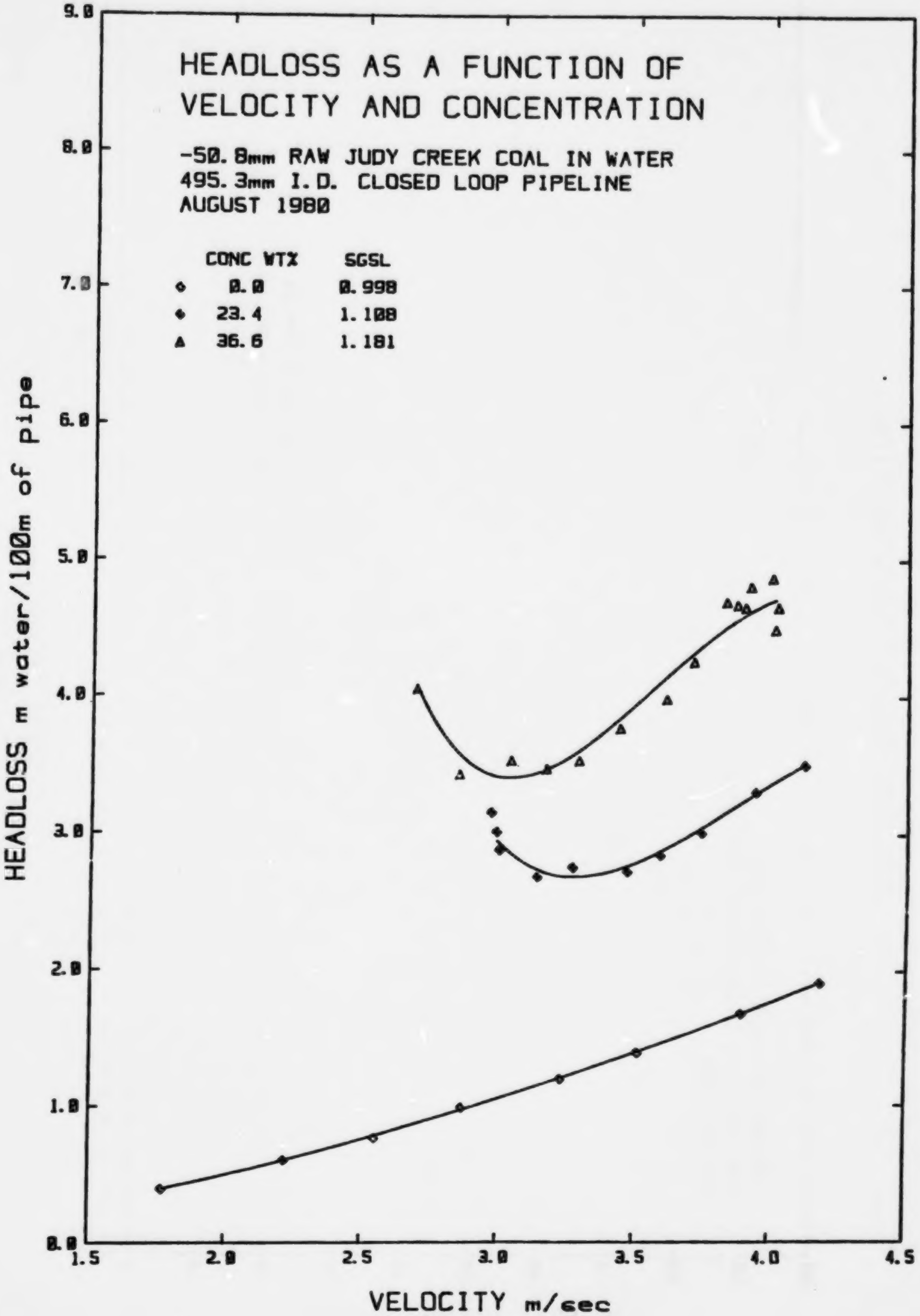

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
CONC WT% SGSL
◇ 0.0 0.998
◆ 23.4 1.108
△ 36.6 1.181
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Figure 50

SOLIDS SIZE DISTRIBUTION

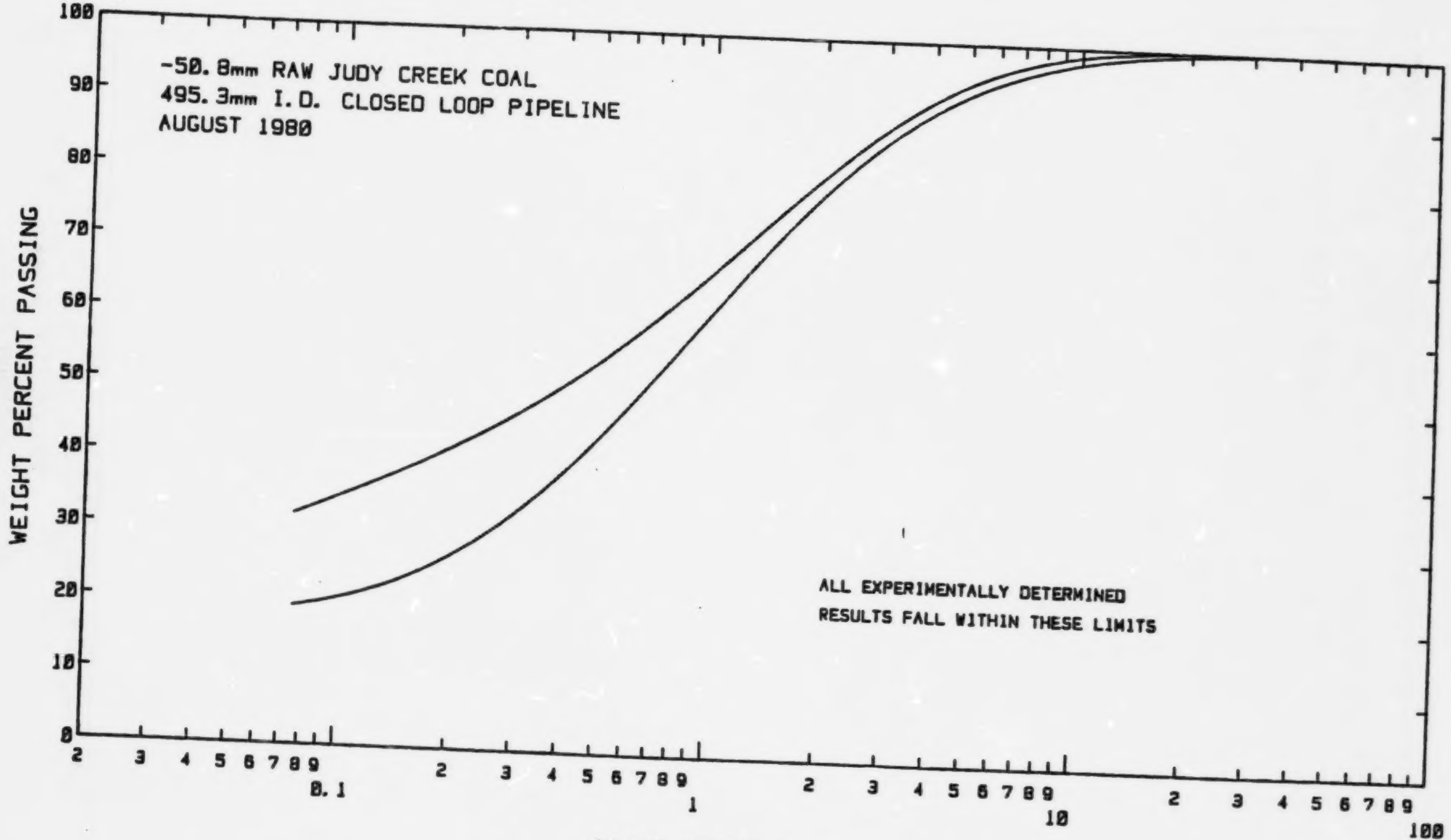


Figure 51

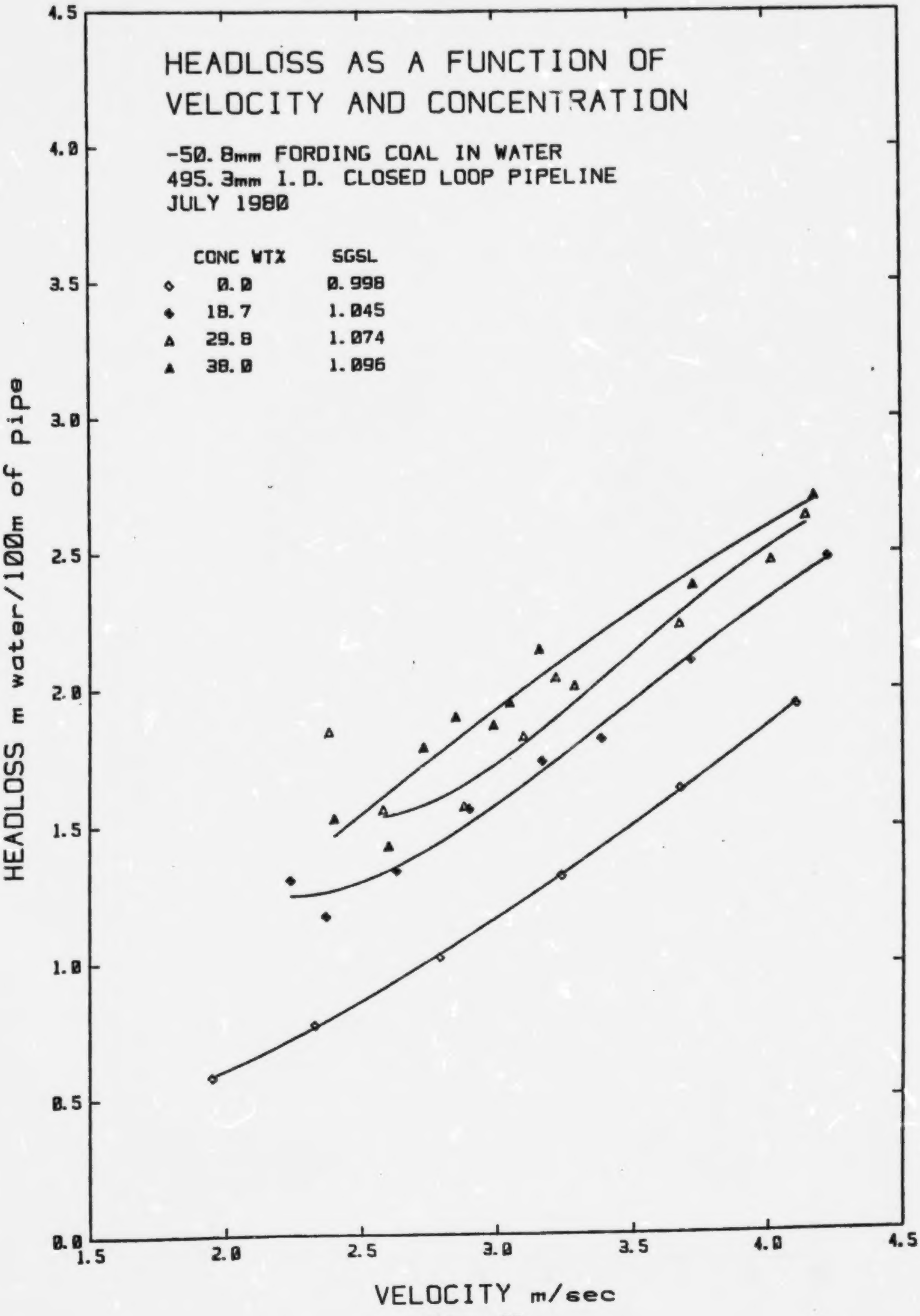

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
JULY 1980
CONC WT%
SGSL
◇ 0.0 0.998
◆ 18.7 1.045
△ 29.8 1.074
▲ 38.0 1.096
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Figure 52

SOLIDS SIZE DISTRIBUTION

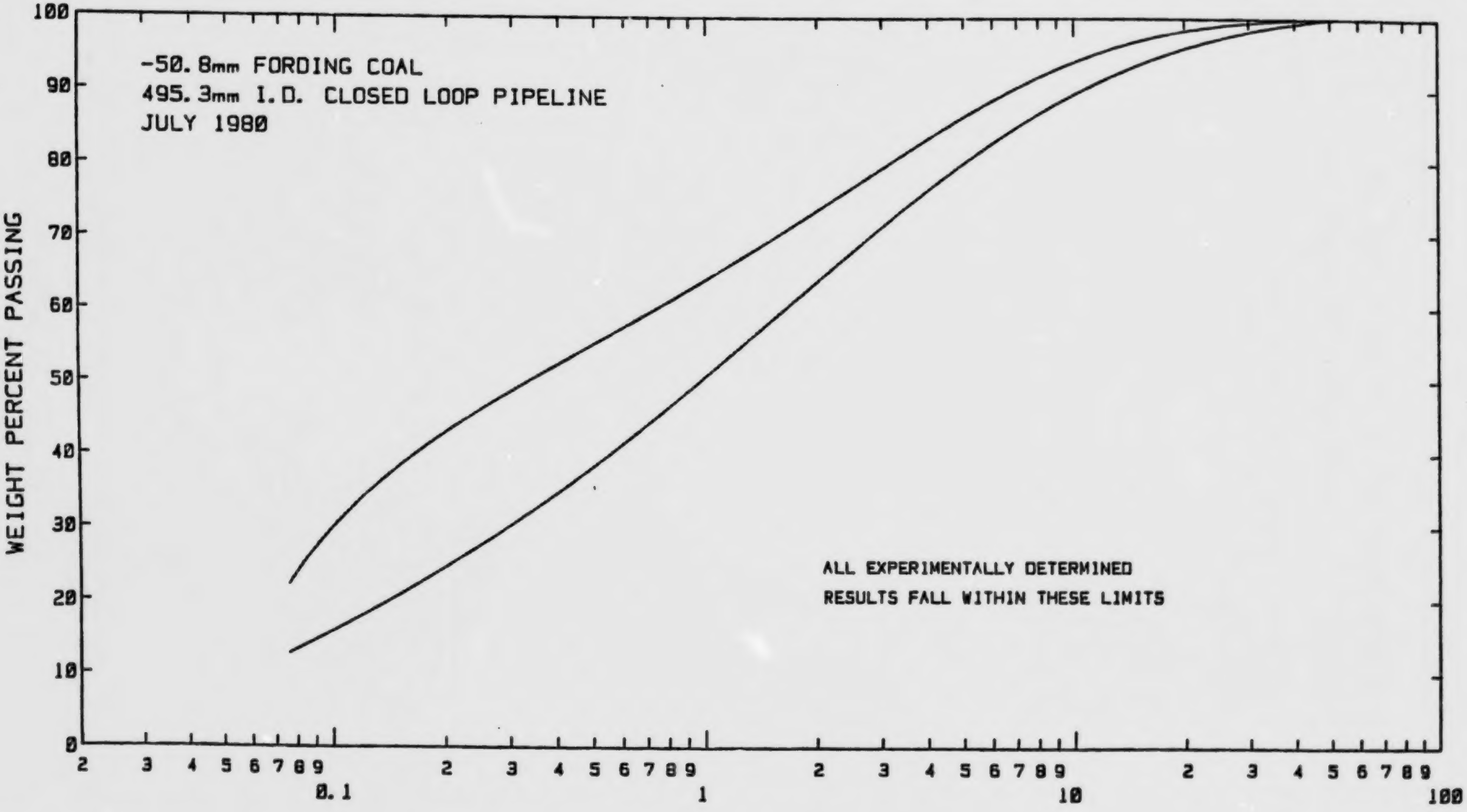


Figure 53

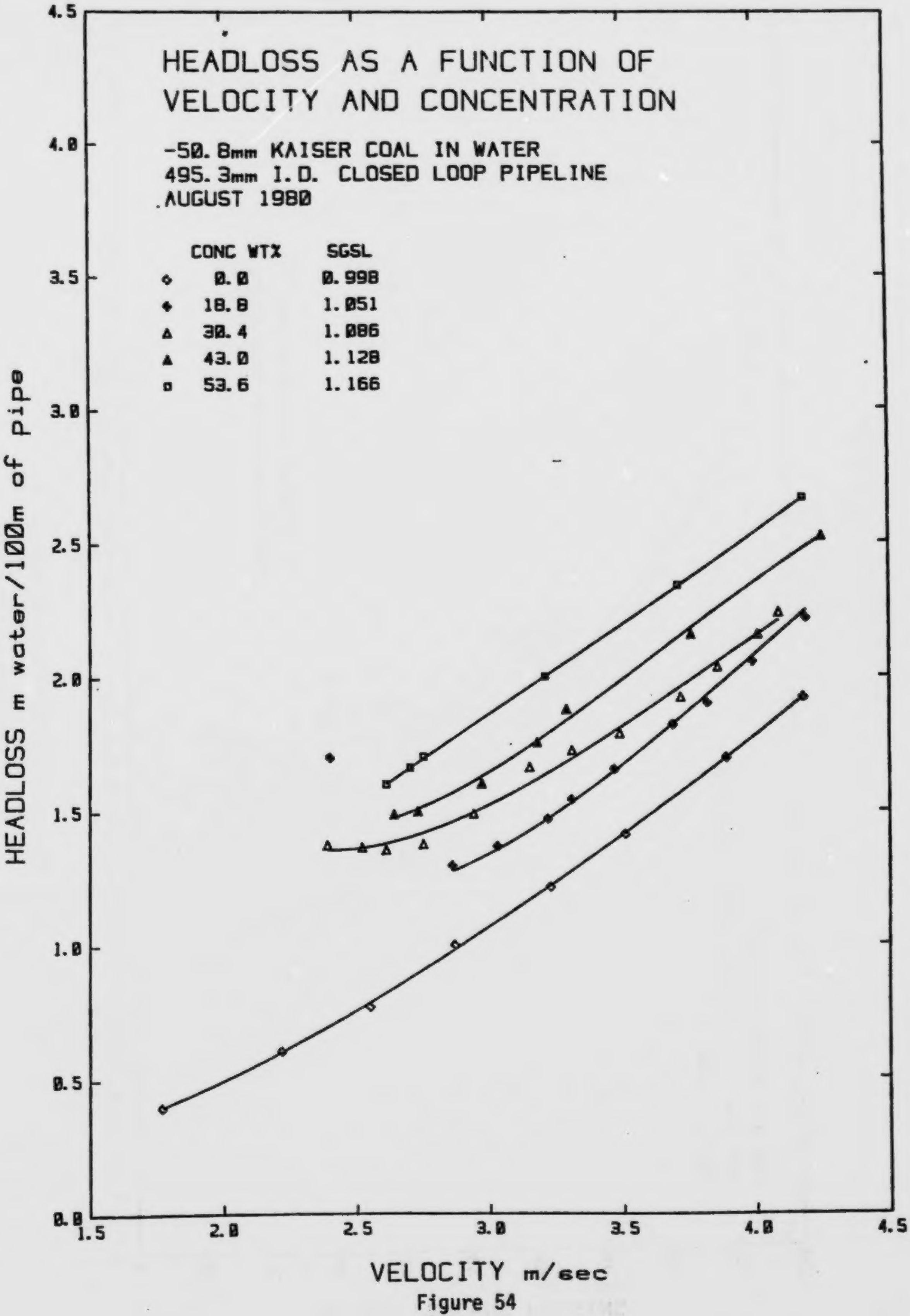

HEADLOSS AS A FUNCTION OF VELOCITY AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
CONC WT% SGSL
◇ 0.0 0.998
◆ 18.8 1.051
△ 30.4 1.086
▲ 43.0 1.128
□ 53.6 1.166
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Figure 54

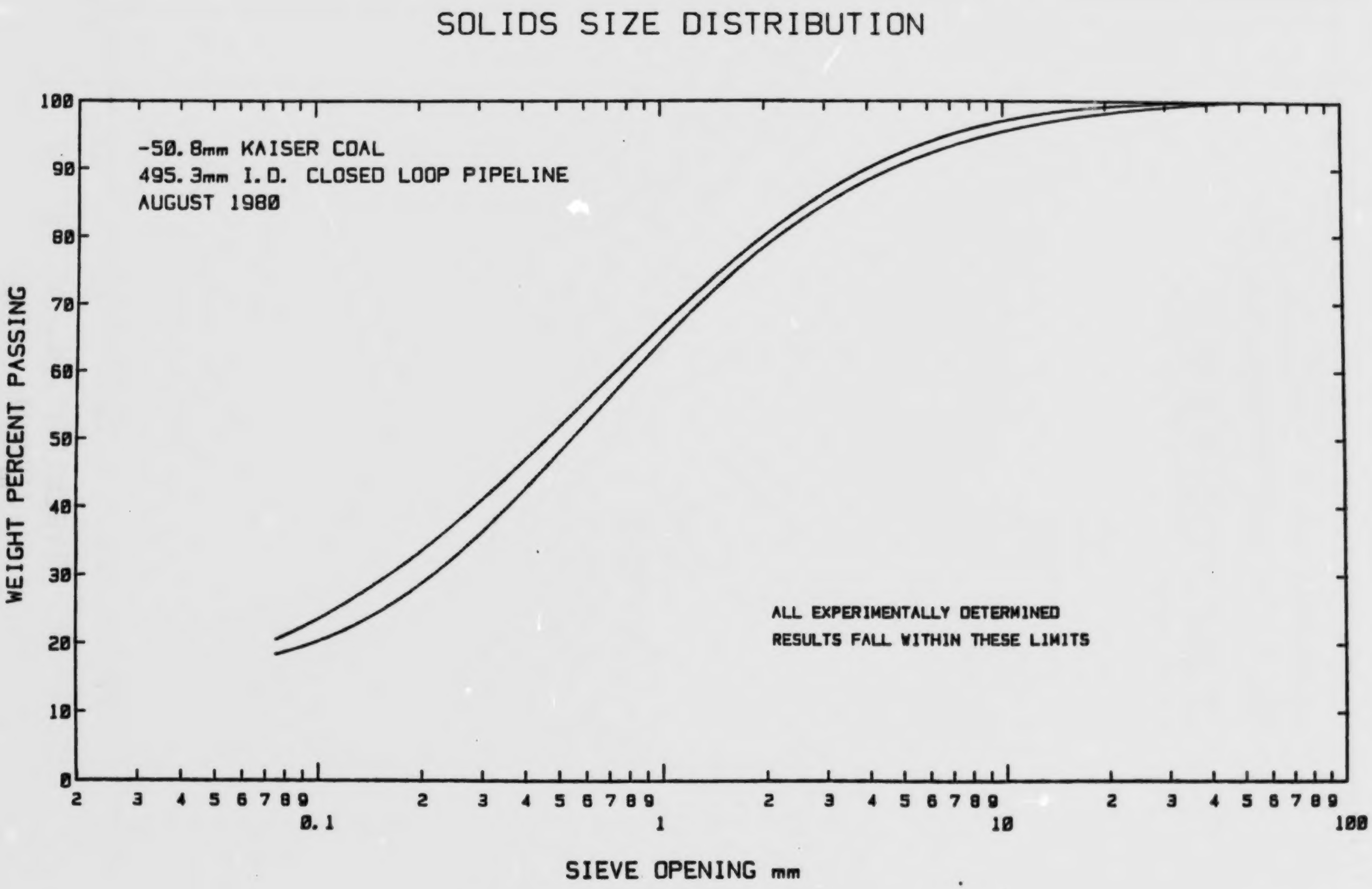

SOLIDS SIZE DISTRIBUTION
-50.8mm KAISER COAL
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
ALL EXPERIMENTALLY DETERMINED
RESULTS FALL WITHIN THESE LIMITS
WEIGHT PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
2 3 4 5 6 7 8 9
0.1
2 3 4 5 6 7 8 9
1
2 3 4 5 6 7 8 9
10
2 3 4 5 6 7 8 9
100
SIEVE OPENING mm

Figure 55

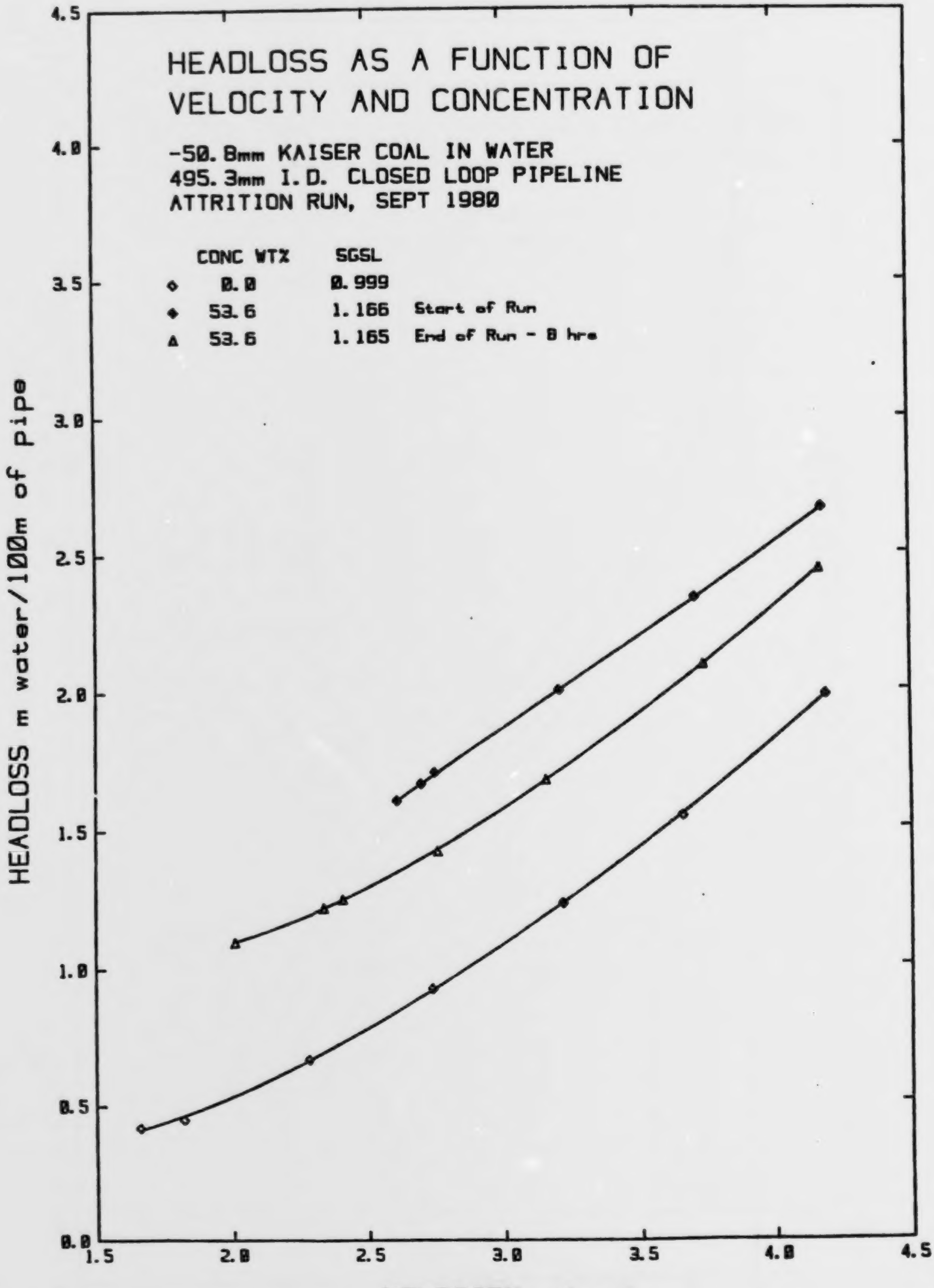

HEADLOSS AS A FUNCTION OF
VELOCITY AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
CONC WT%
SGSL
◇ 0.0 0.999
◆ 53.6 1.166 Start of Run
△ 53.6 1.165 End of Run - 8 hrs
HEADLOSS m water/100m of pipe
VELOCITY m/sec
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Figure 56

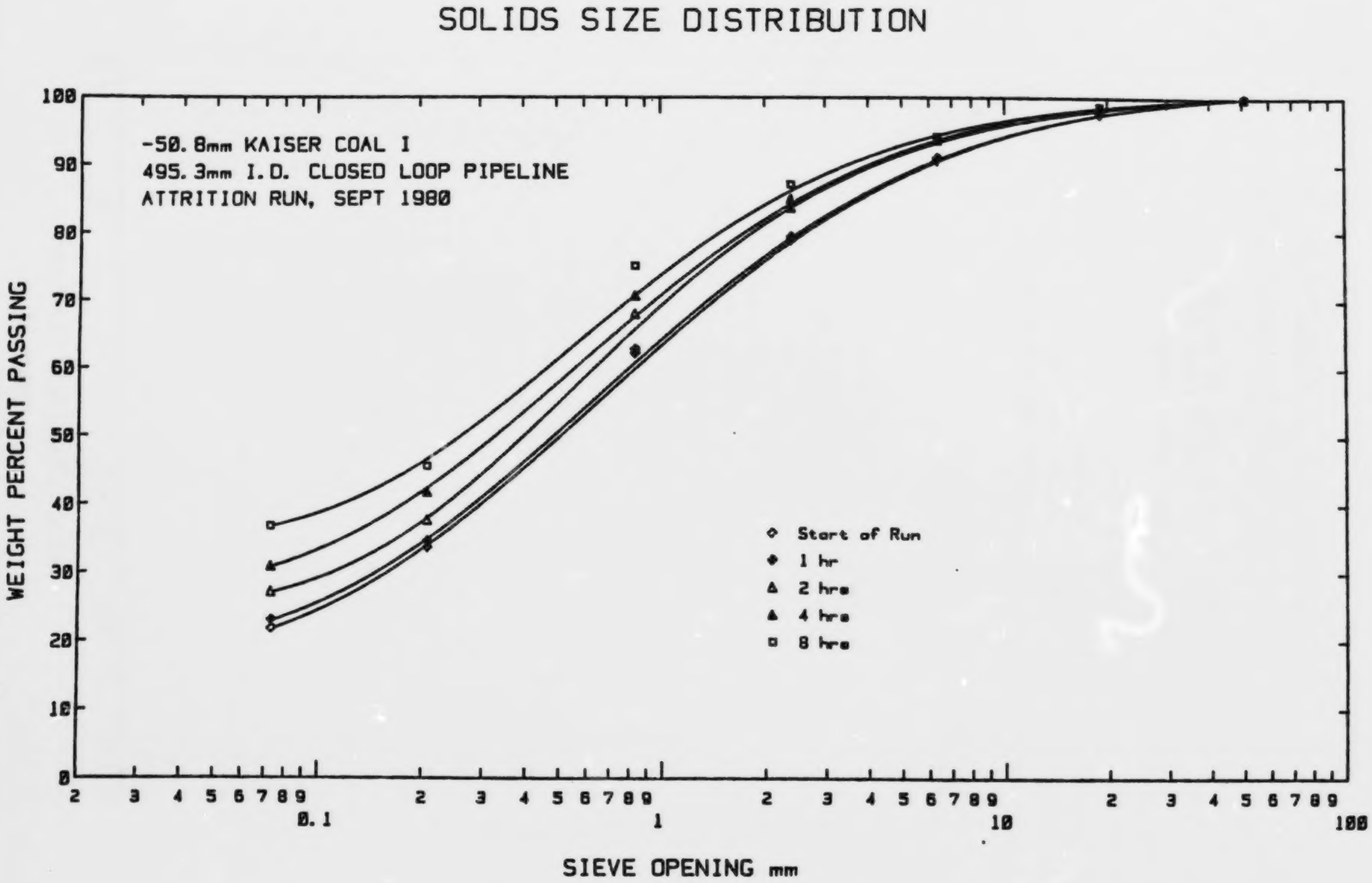

SOLIDS SIZE DISTRIBUTION
-50.8mm KAISER COAL I
495.3mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
WEIGHT PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
2
3
4
5
6
7
8
9
0.1
1
10
100
SIEVE OPENING mm
◇ Start of Run
◆ 1 hr
△ 2 hrs
▲ 4 hrs
□ 8 hrs

Figure 57

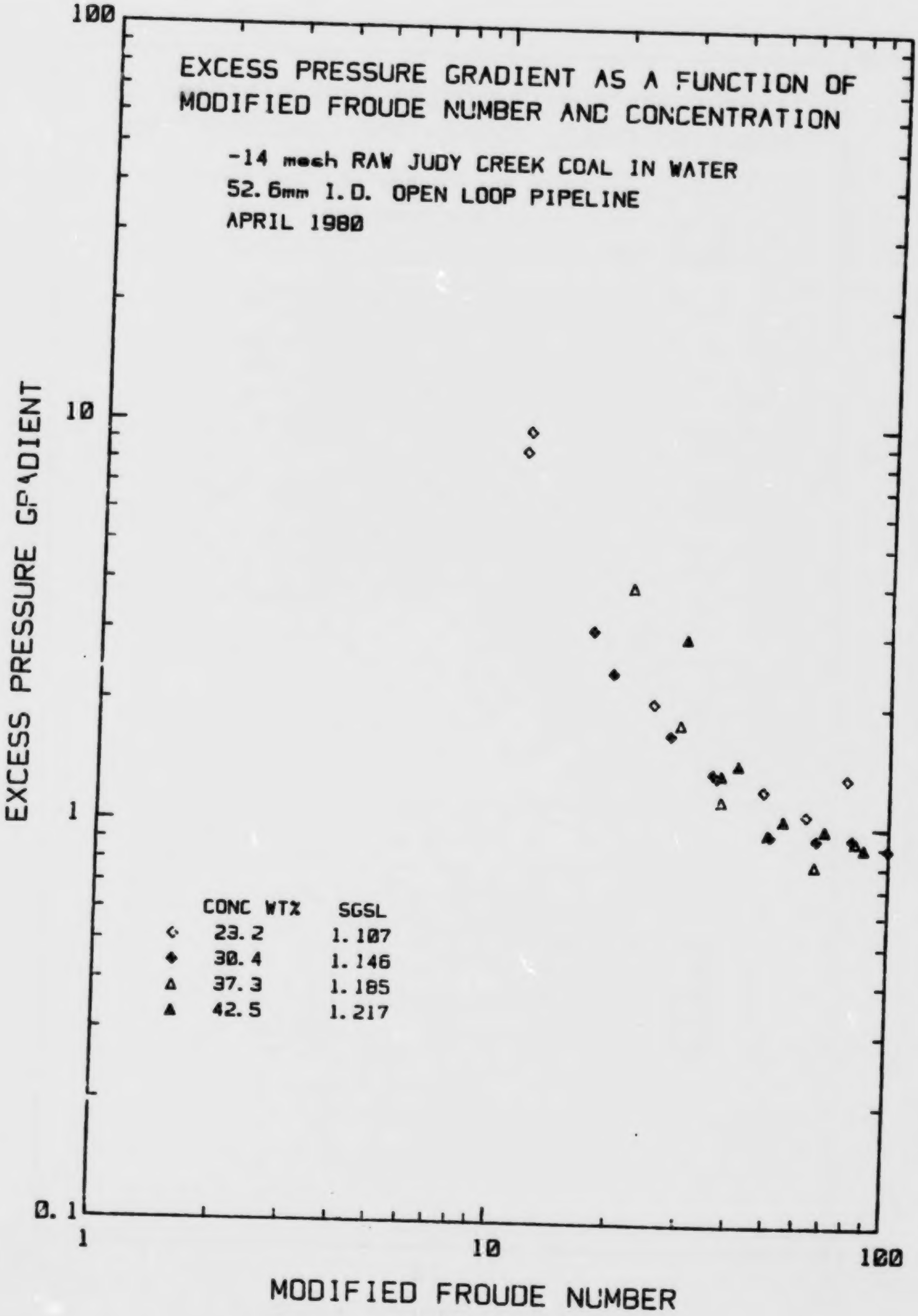

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-14 mesh RAW JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
APRIL 1980
CONC WT% SGSL
◇ 23.2 1.107
◆ 30.4 1.146
△ 37.3 1.185
▲ 42.5 1.217
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 58

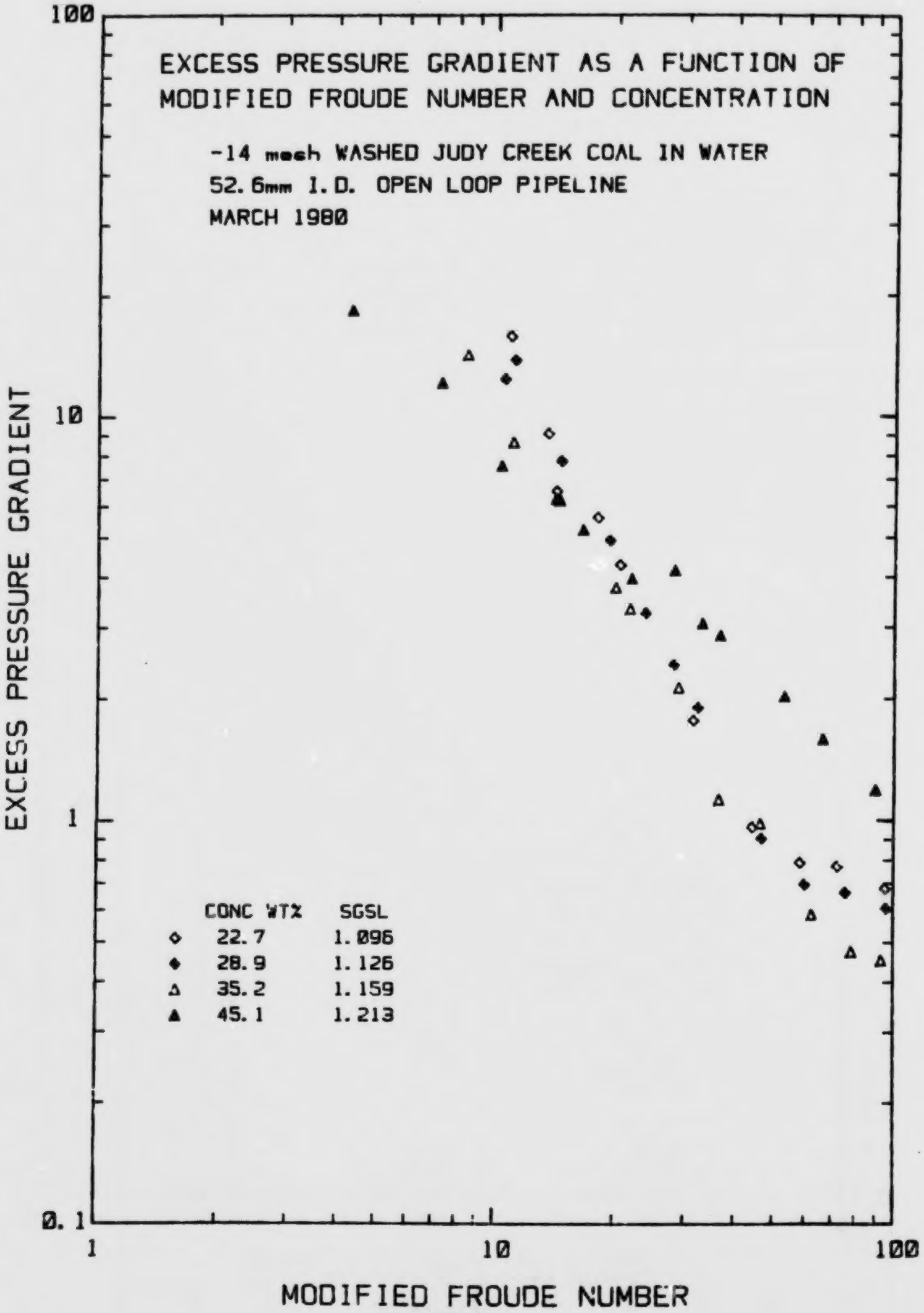

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-14 mesh WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980
CONC WT% SGSL
◇ 22.7 1.096
◆ 28.9 1.126
△ 35.2 1.159
▲ 45.1 1.213
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 59

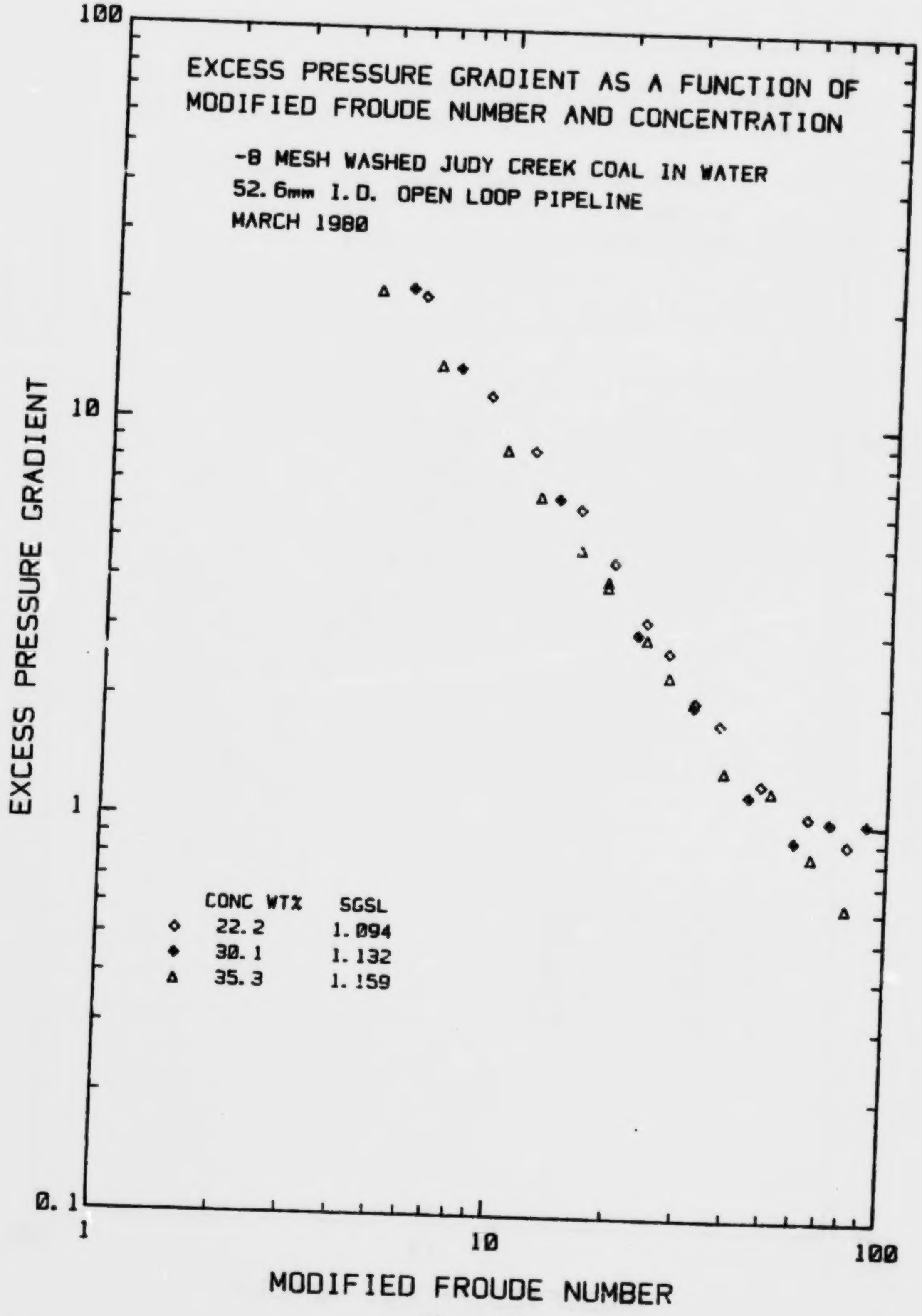

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-8 MESH WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980
CONC WT% SGSL
◇ 22.2 1.094
◆ 30.1 1.132
△ 35.3 1.159
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 60

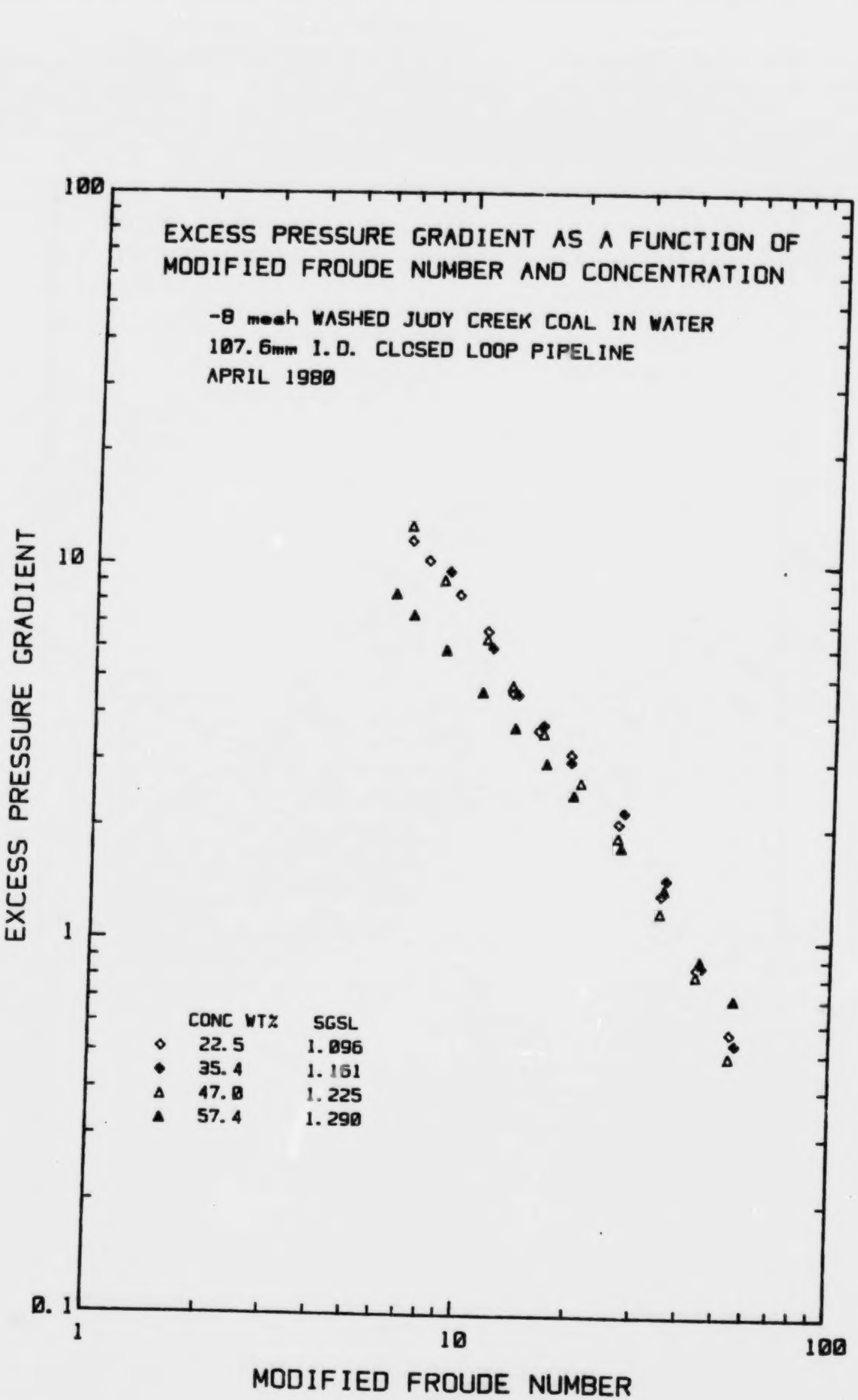

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-8 mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980
CONC WT%
SGSL
◇ 22.5 1.096
◆ 35.4 1.161
△ 47.0 1.225
▲ 57.4 1.290
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 61

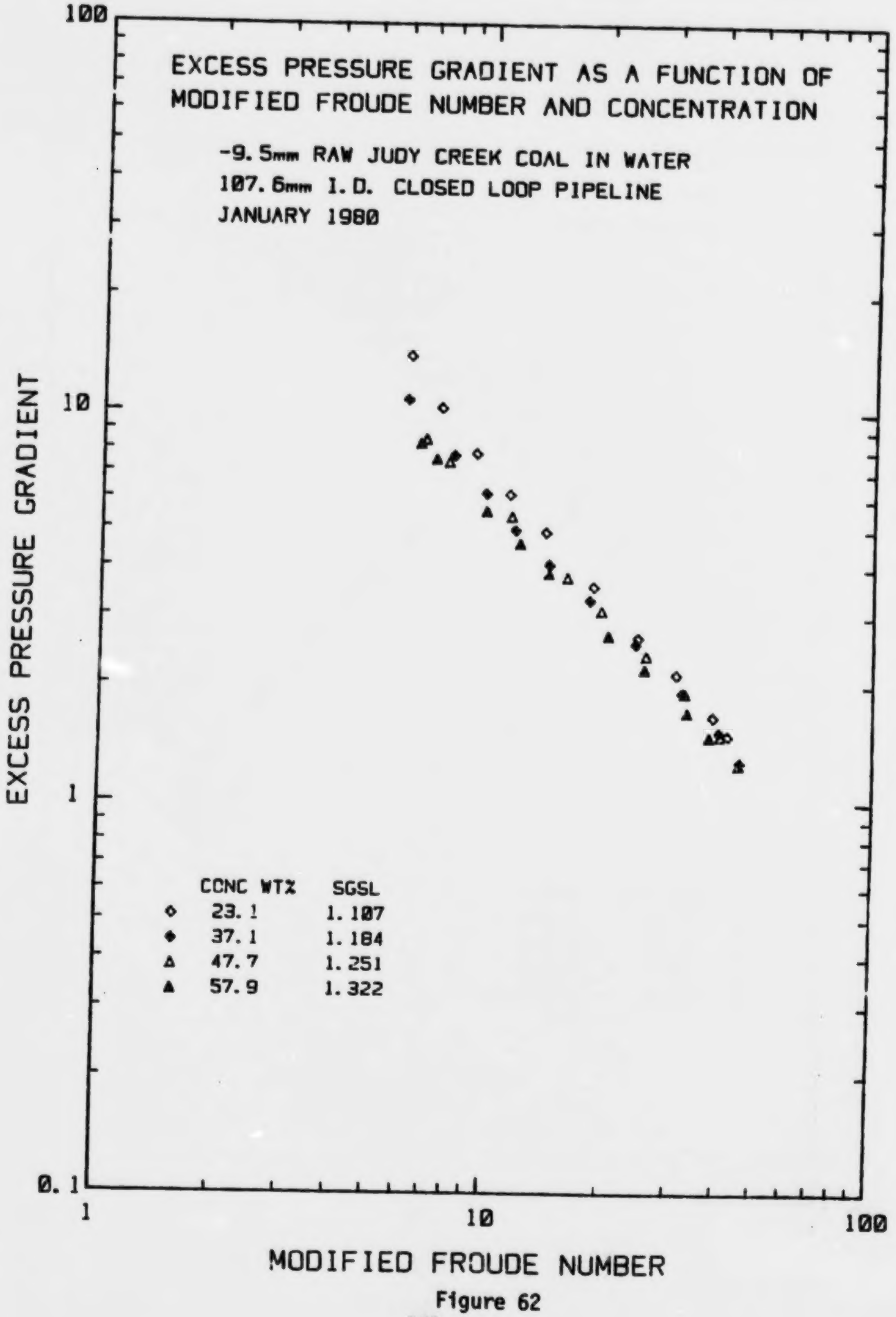

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm RAW JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980
CONC WT%
SGSL
◇ 23.1 1.107
◆ 37.1 1.184
△ 47.7 1.251
▲ 57.9 1.322
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
100
10
1
0.1
1
10
100

Figure 62

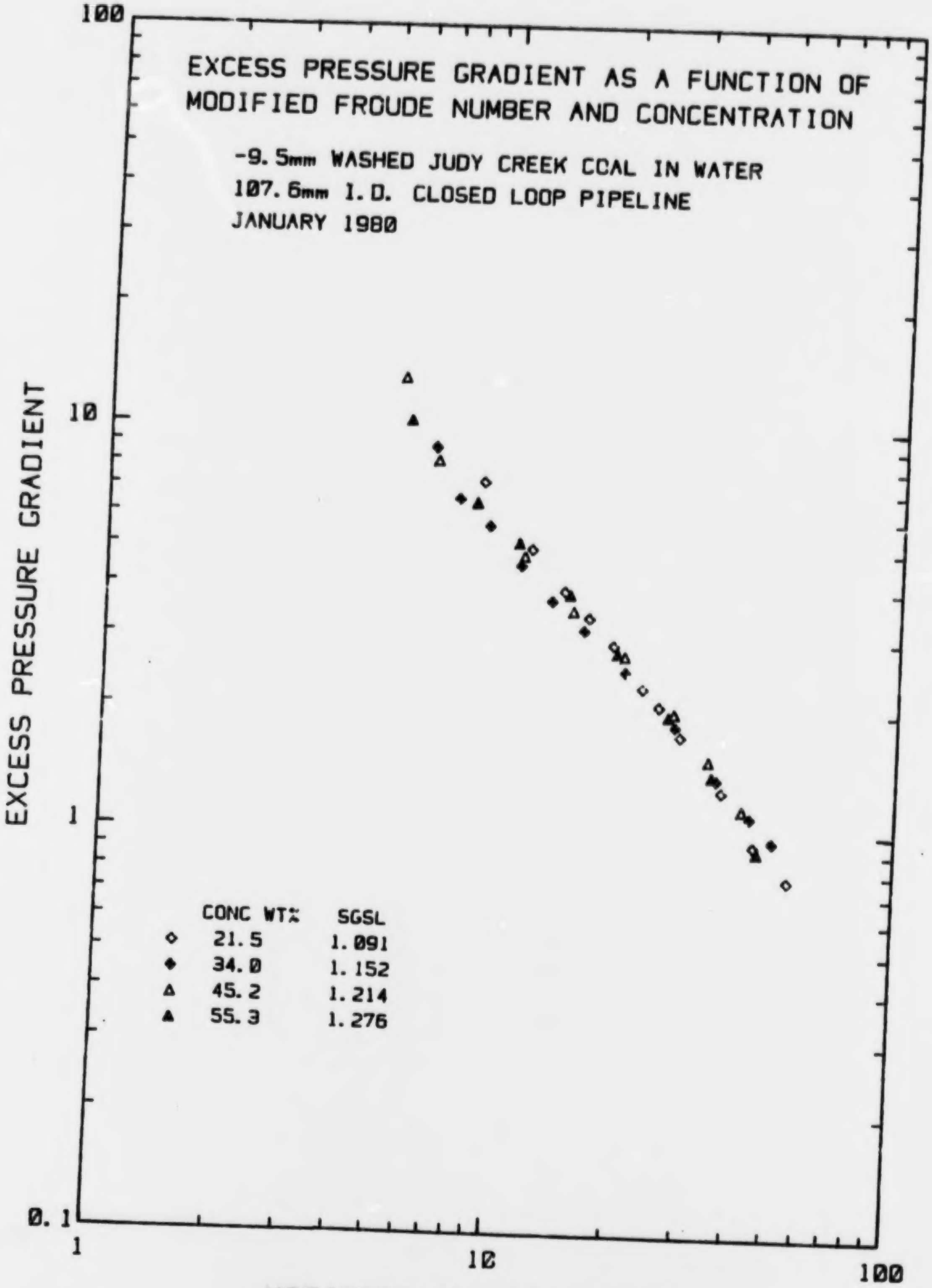

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
CONC WT%
SGSL
◇ 21.5 1.091
◆ 34.0 1.152
△ 45.2 1.214
▲ 55.3 1.276

Figure 63

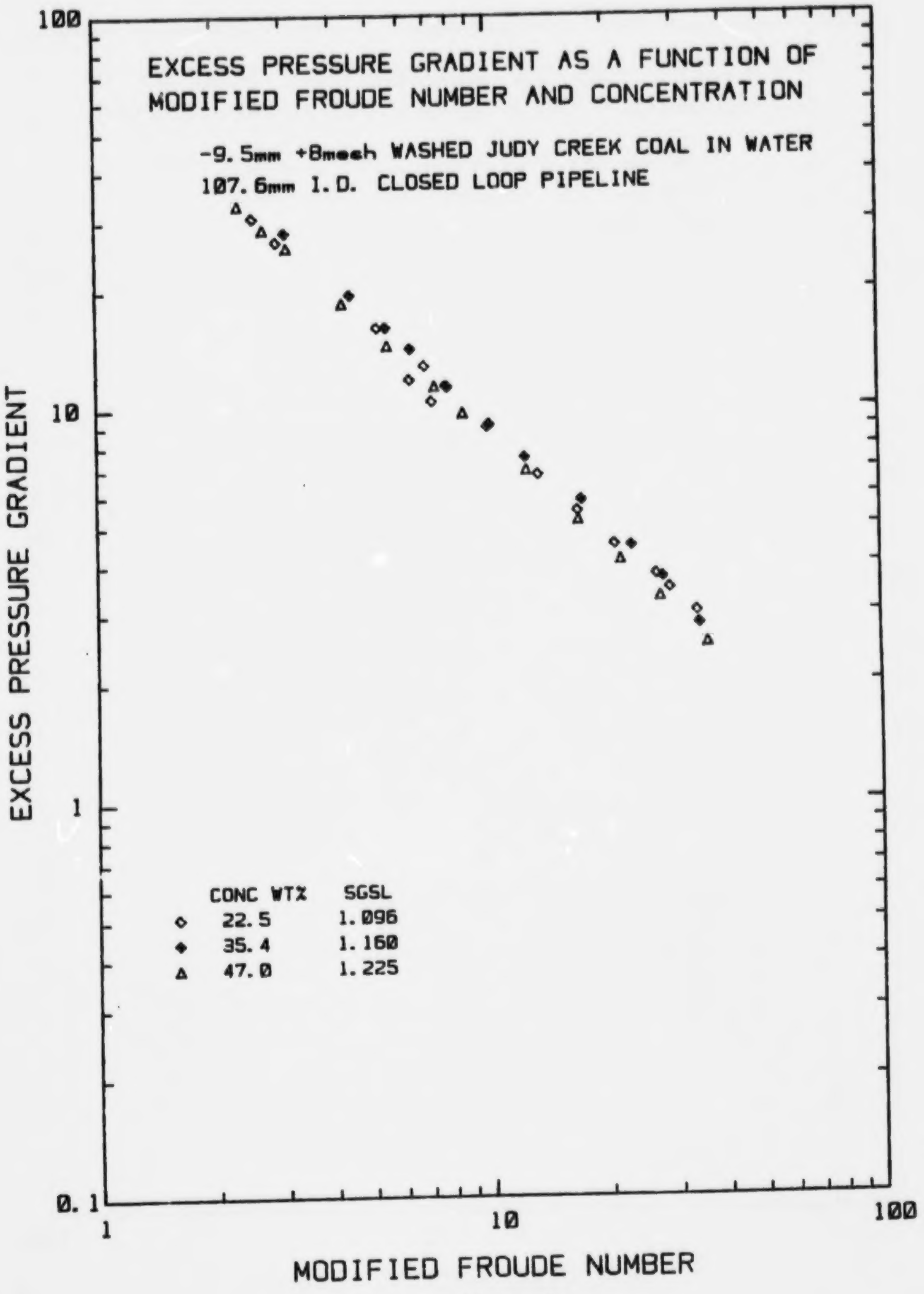

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm +8mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
CONC WT% SGSL
◇ 22.5 1.096
◆ 35.4 1.160
△ 47.0 1.225
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 64

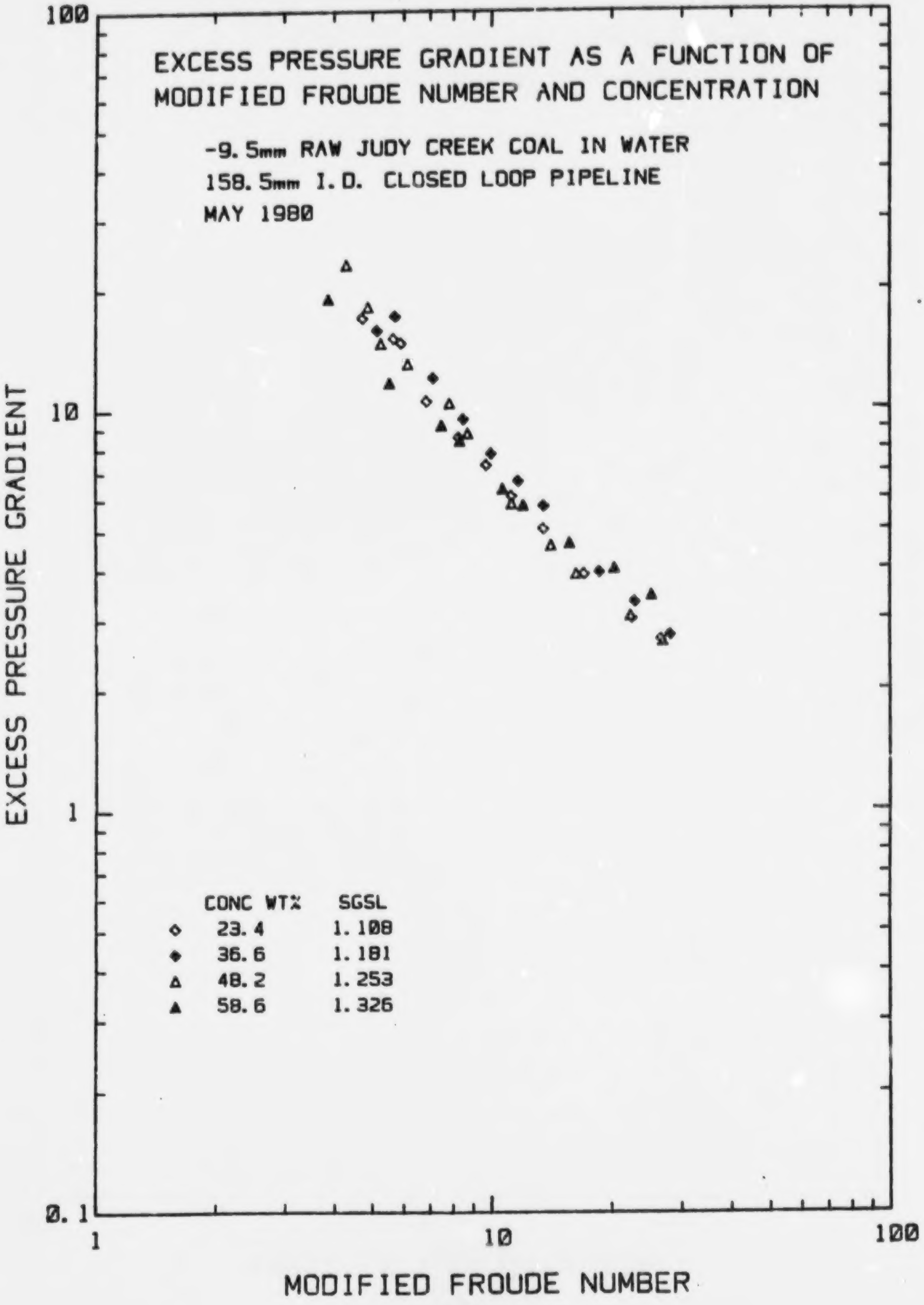

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980
CONC WT%
SGSL
◇ 23.4 1.108
◆ 36.6 1.181
△ 48.2 1.253
▲ 58.6 1.326
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 65

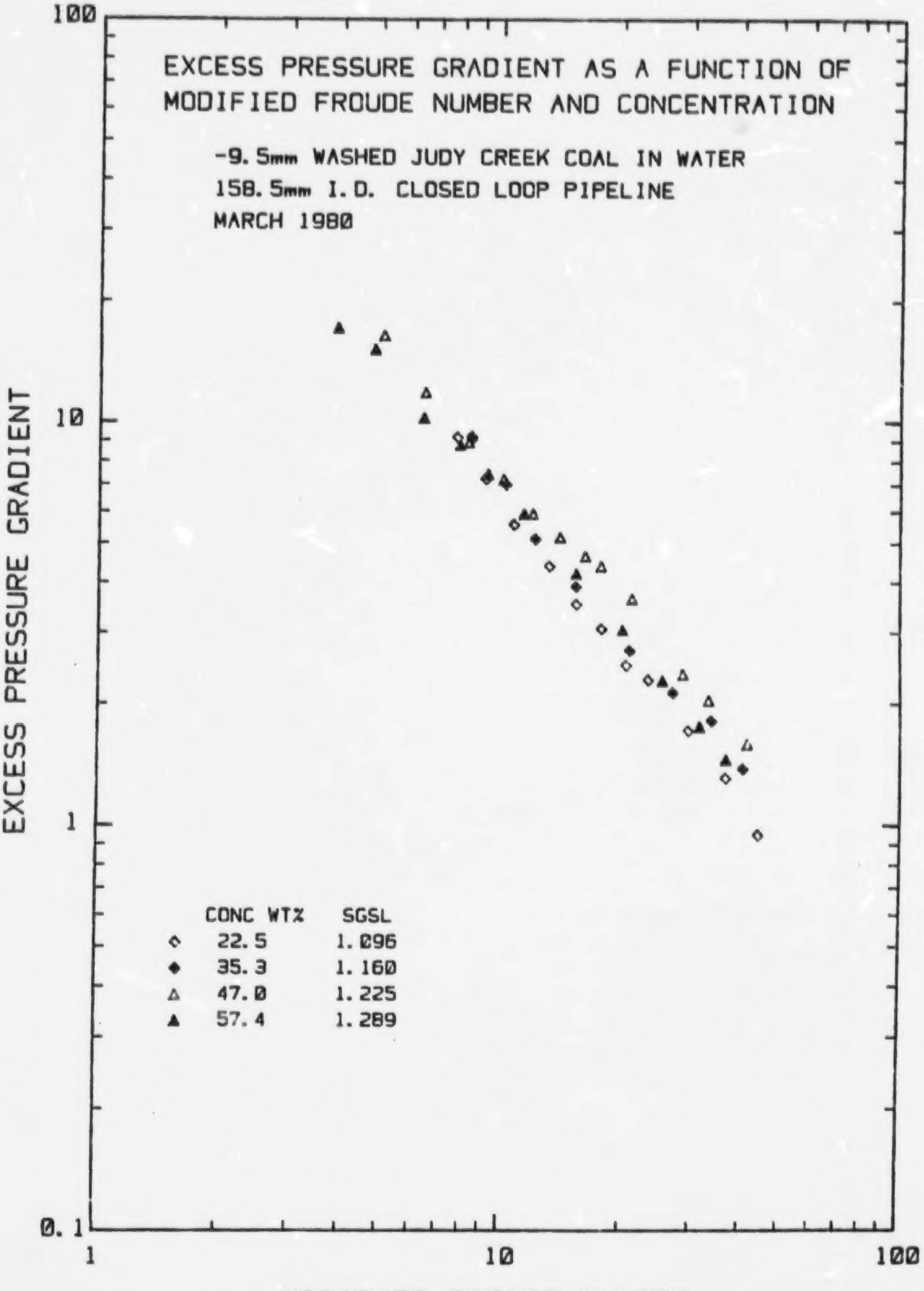

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm WASHED JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MARCH 1980
CONC WT%
SGSL
◇ 22.5 1.096
◆ 35.3 1.160
△ 47.0 1.225
▲ 57.4 1.289
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
100
10
1
0.1
1
10
100

Figure 66

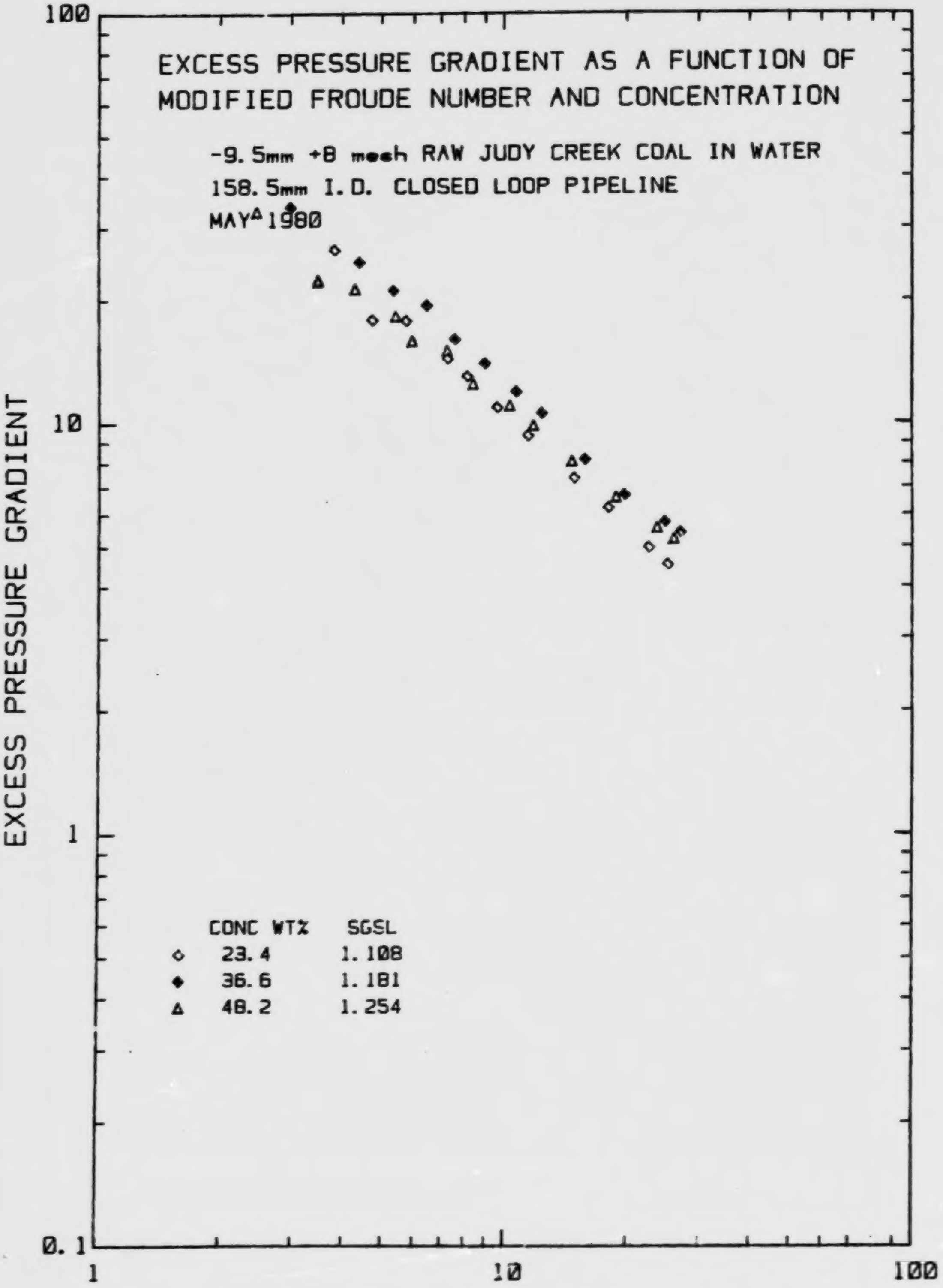
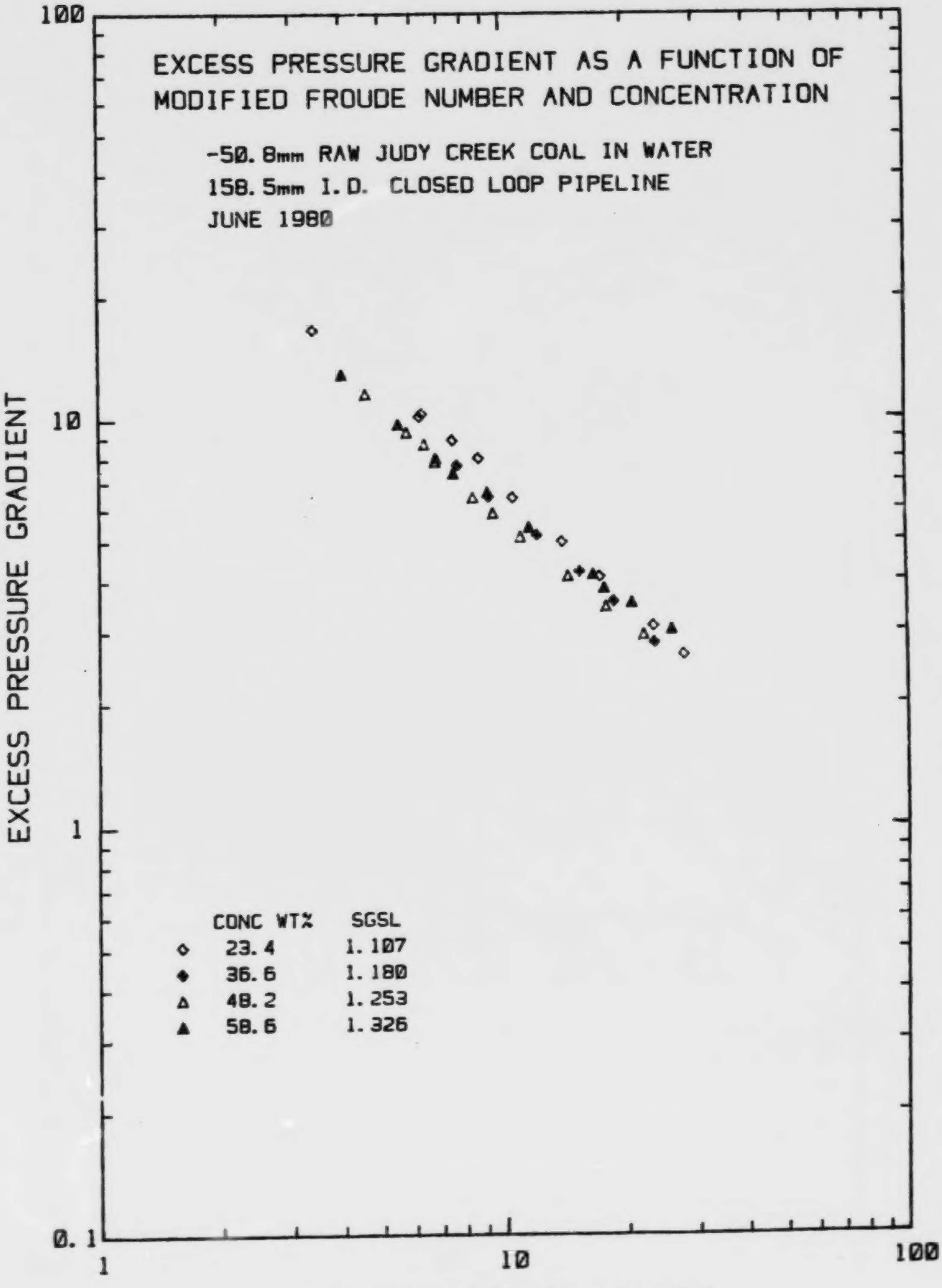
EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-9.5mm +8 mesh RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980
CONC WT%
SGSL
◇ 23.4 1.108
◆ 36.6 1.181
△ 48.2 1.254
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
100
10
1
0.1
1
10
100

Figure 67



EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980
100
10
1
0.1
EXCESS PRESSURE GRADIENT
1
10
100
MODIFIED FROUDE NUMBER
CONC WT%
SGSL
◇ 23.4
1.107
◆ 36.6
1.180
△ 48.2
1.253
▲ 58.6
1.326

Figure 68

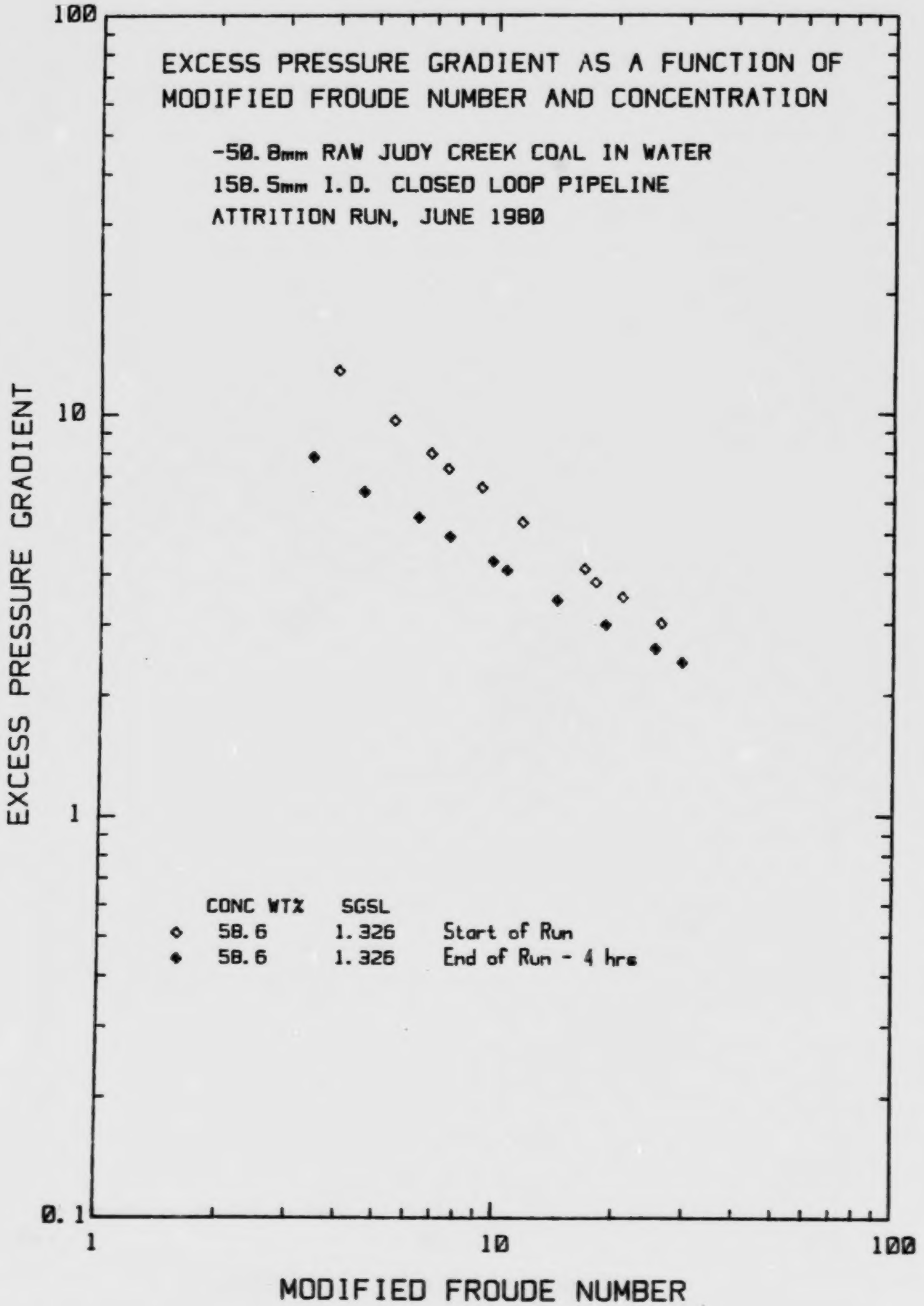

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, JUNE 1980
100
10
1
0.1
EXCESS PRESSURE GRADIENT
CONC WT% SGSL
◇ 58.6 1.326 Start of Run
◆ 58.6 1.326 End of Run - 4 hrs
1
10
100
MODIFIED FROUDE NUMBER

Figure 69

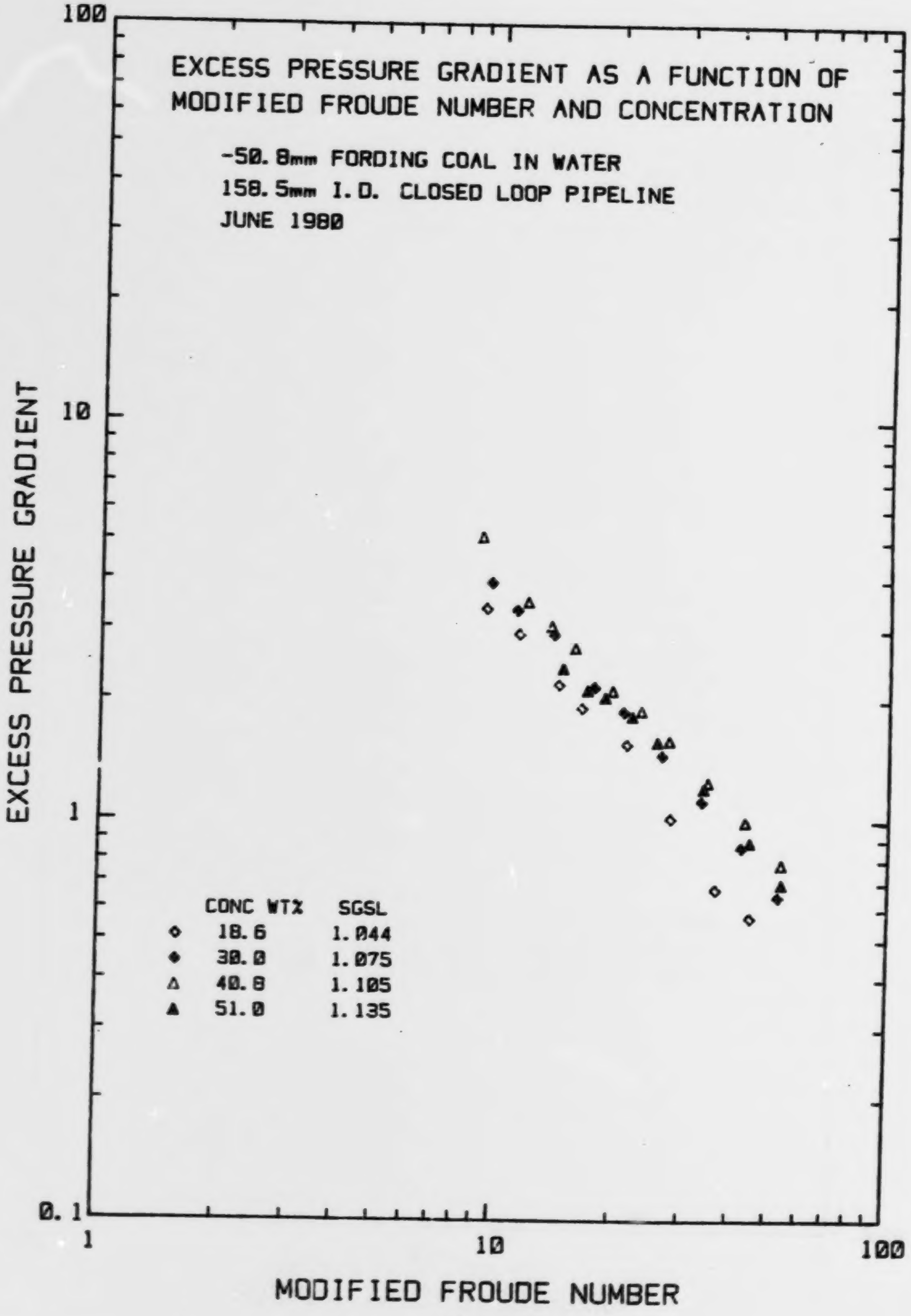

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980
CONC WT% SGSL
◇ 18.6 1.044
◆ 30.0 1.075
△ 40.8 1.105
▲ 51.0 1.135
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 70

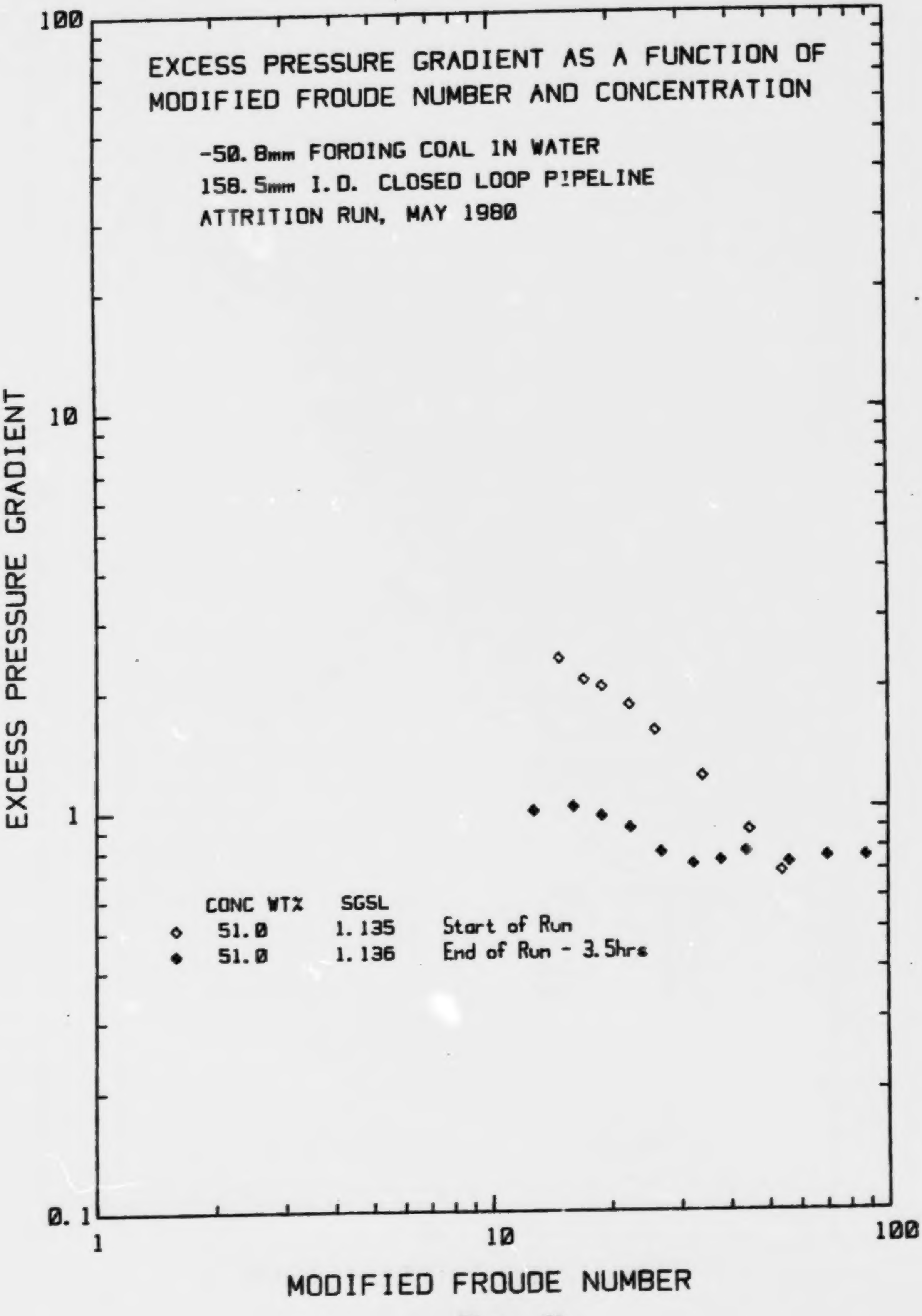

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MAY 1980
CONC WT% SGSL
◇ 51.0 1.135 Start of Run
◆ 51.0 1.136 End of Run - 3.5hrs
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 71

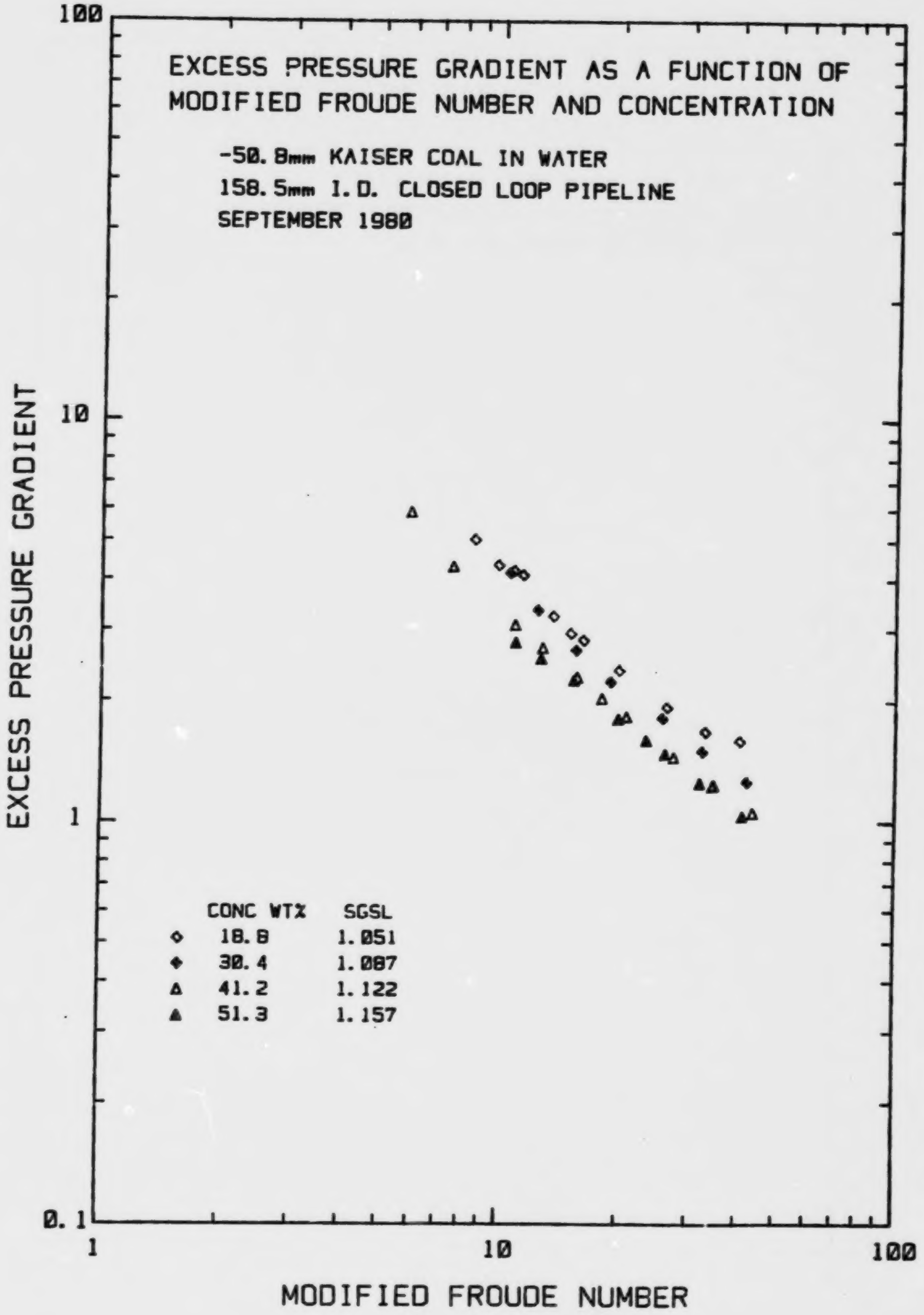

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
SEPTEMBER 1980
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER
CONC WT% SGSL
◇ 18.8 1.051
◆ 30.4 1.087
△ 41.2 1.122
▲ 51.3 1.157

Figure 72

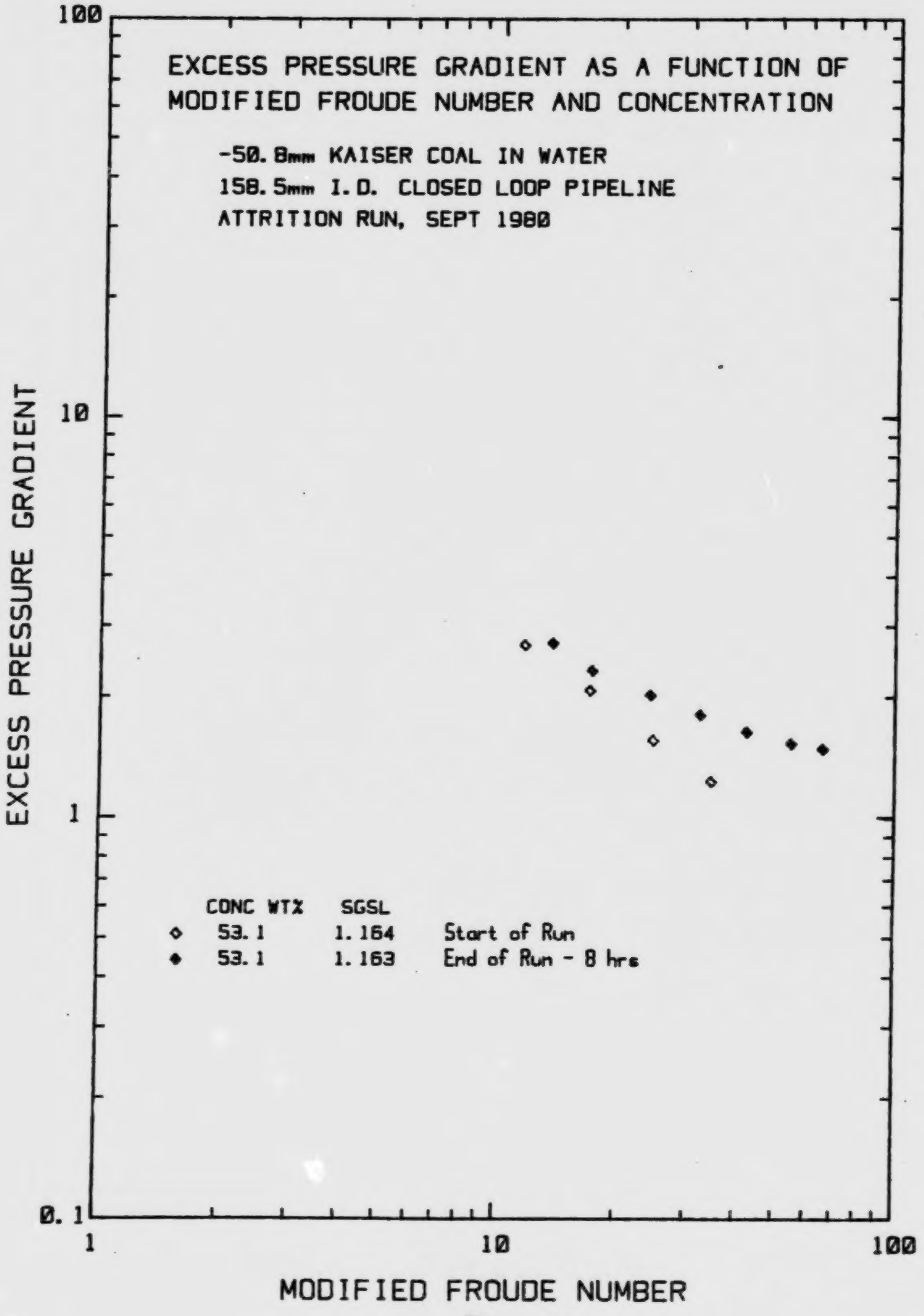

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
CONC WT%
SGSL
◇ 53.1 1.164 Start of Run
◆ 53.1 1.163 End of Run - 8 hrs
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 73

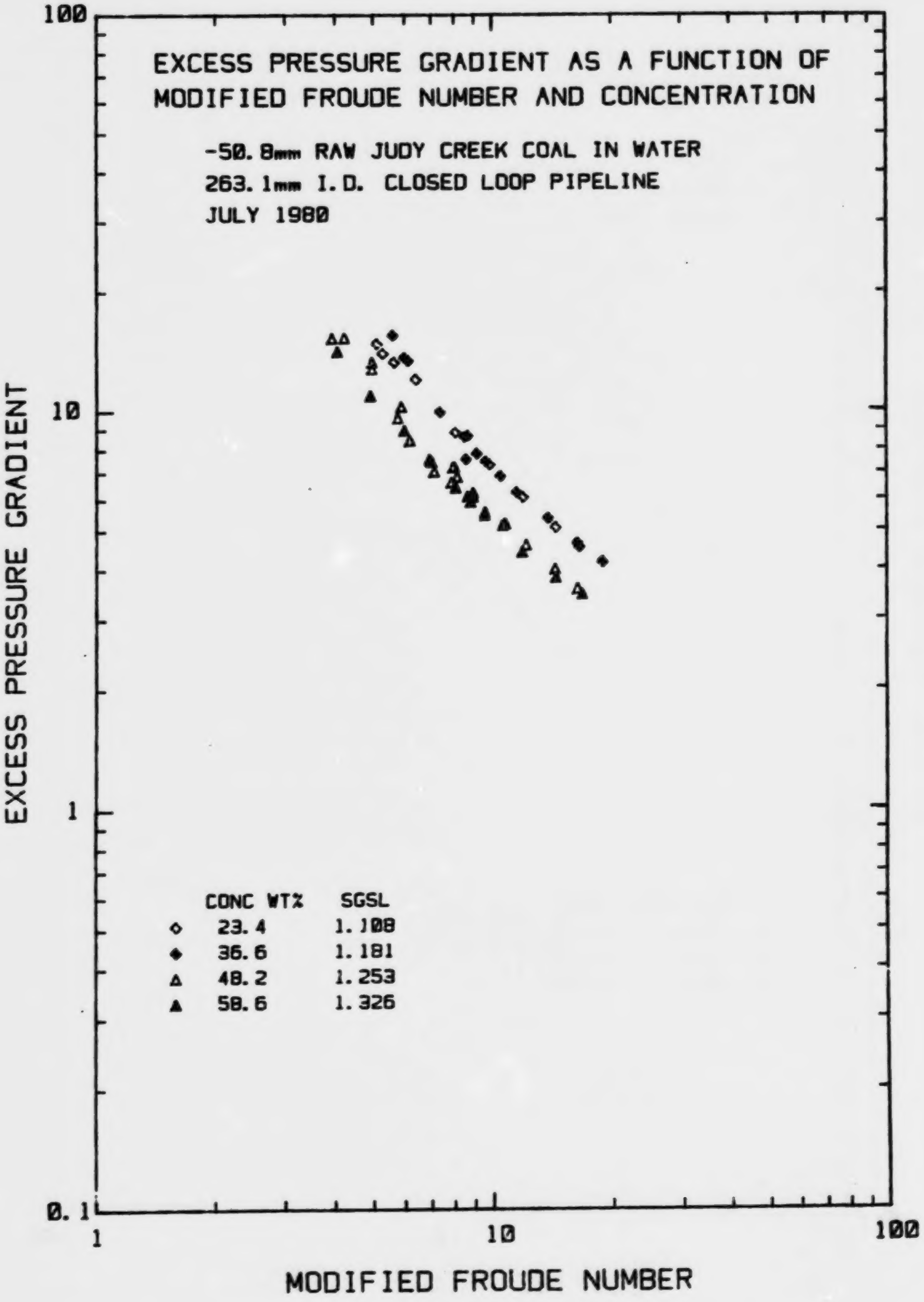

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980
CONC WT% SGSL
◇ 23.4 1.108
◆ 36.6 1.181
△ 48.2 1.253
▲ 58.6 1.326
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 74

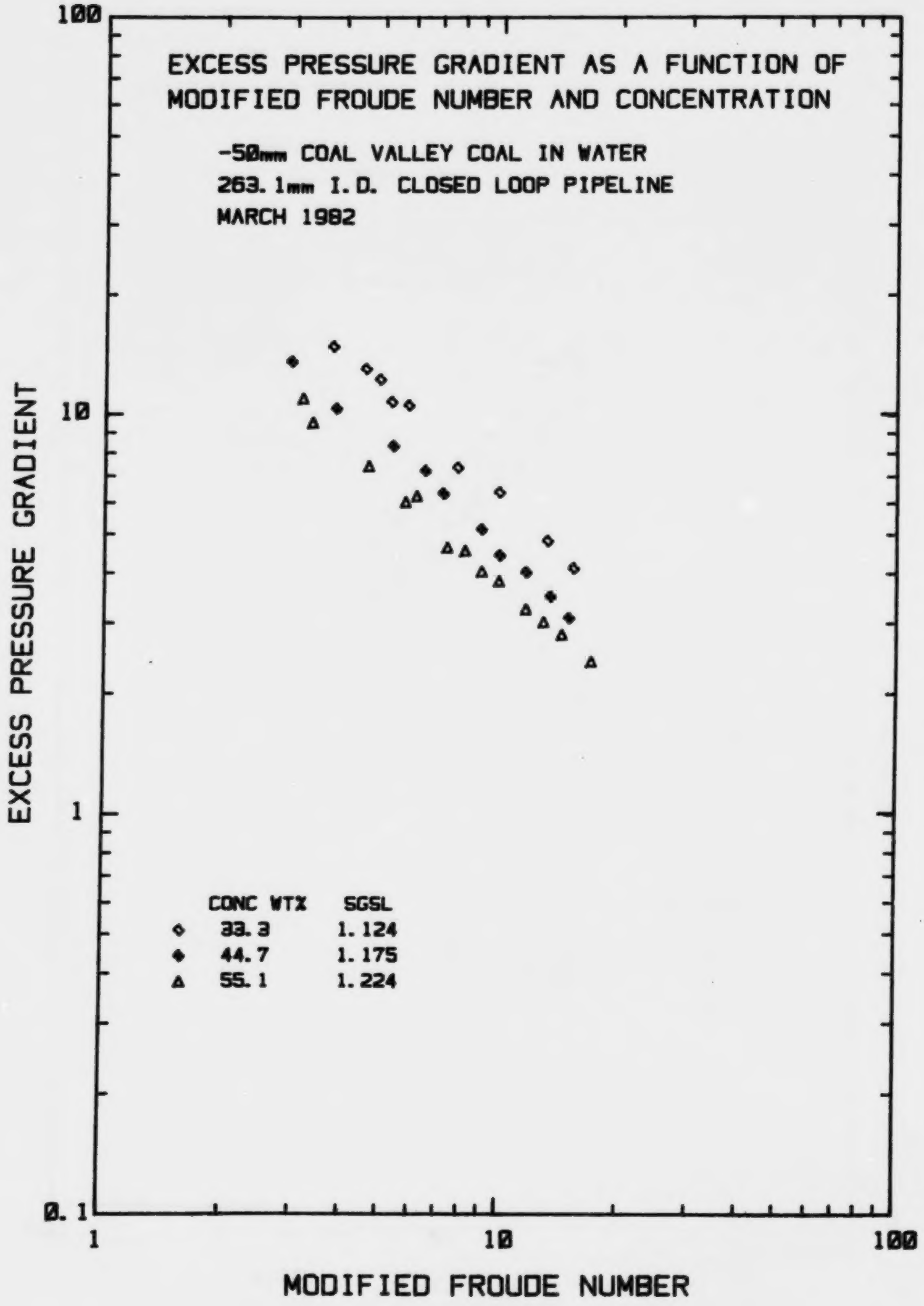

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
MARCH 1982
CONC WT% SGSL
◇ 33.3 1.124
◆ 44.7 1.175
△ 55.1 1.224
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 75

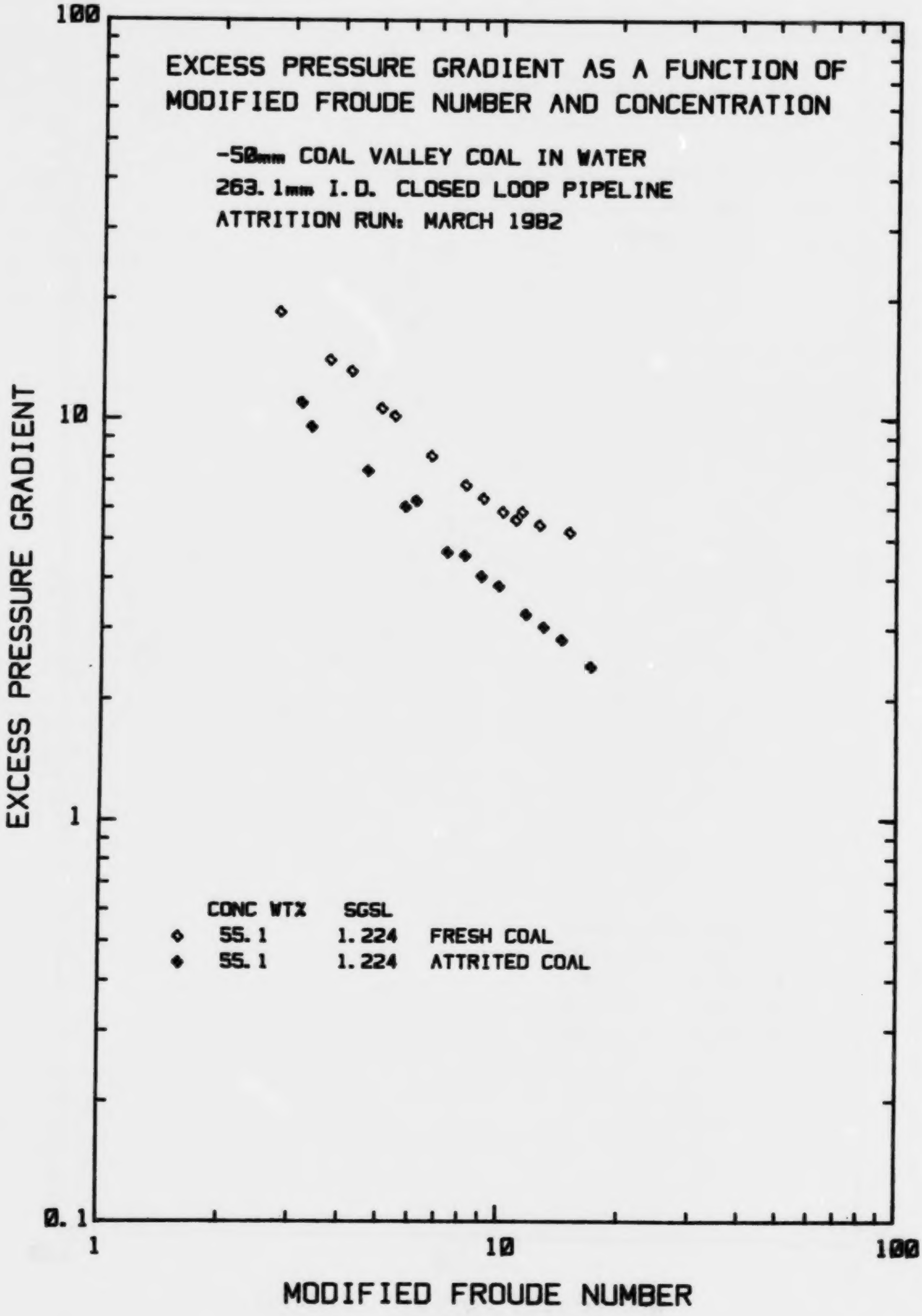

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN: MARCH 1982
CONC WT% SGSL
◇ 55.1 1.224 FRESH COAL
◆ 55.1 1.224 ATTRITED COAL
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 76

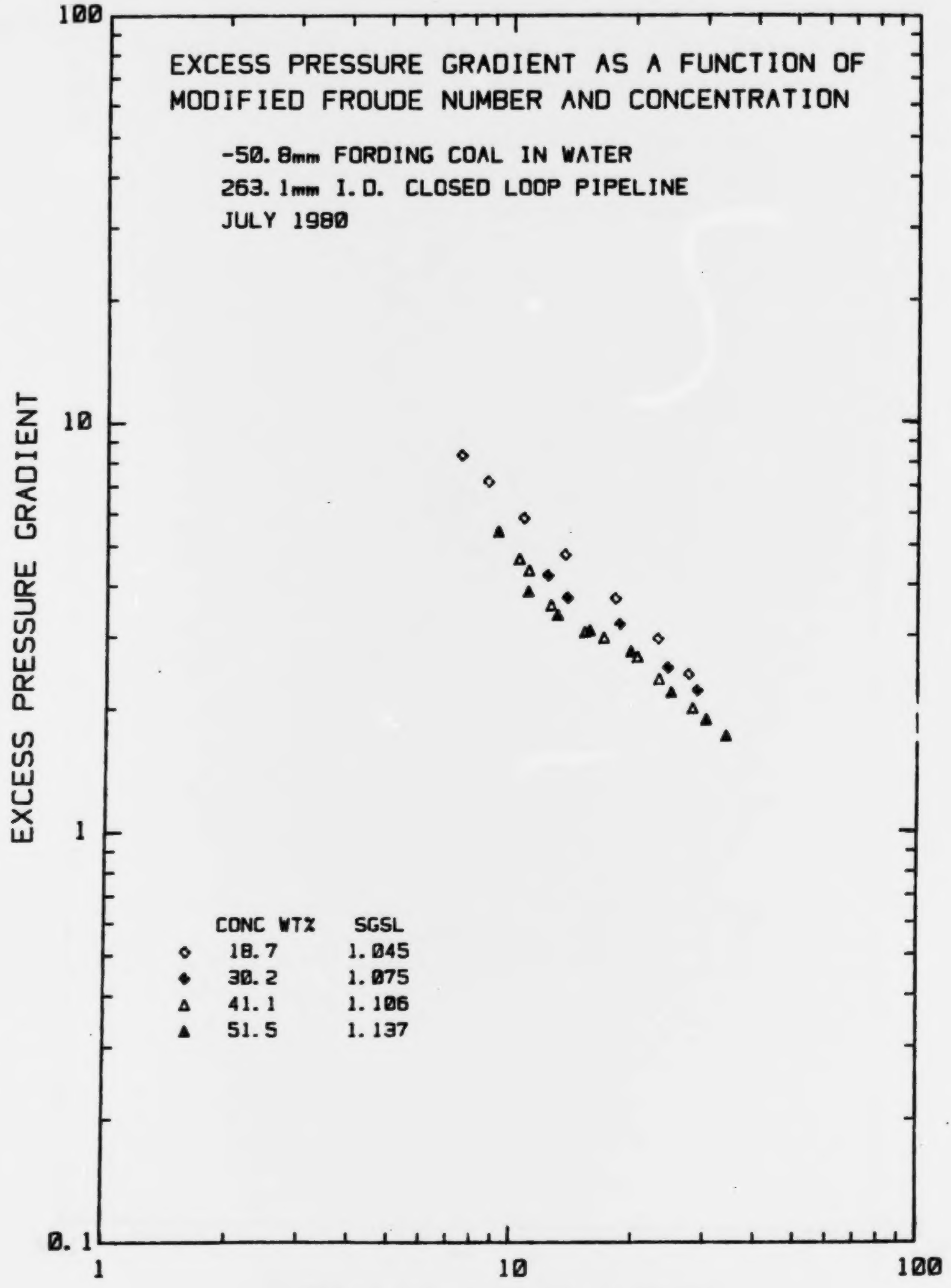

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
100
10
1
0.1
1
10
100
CONC WT%
SGSL
◇ 18.7 1.045
◆ 30.2 1.075
△ 41.1 1.106
▲ 51.5 1.137

Figure 77

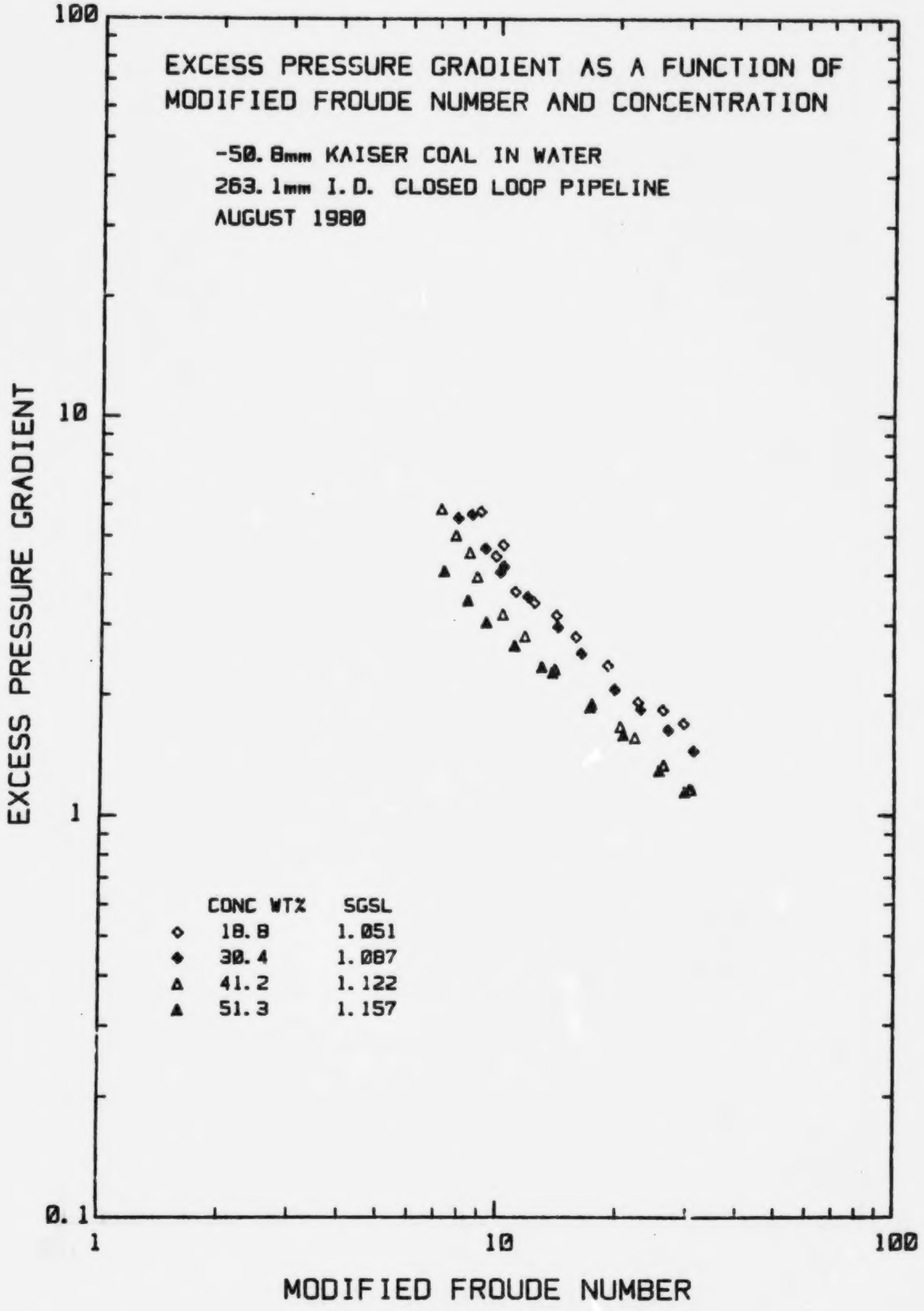

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
100
10
1
0.1
1
10
100
CONC WT% SGSL
◇ 18.8 1.051
◆ 30.4 1.087
△ 41.2 1.122
▲ 51.3 1.157

Figure 78

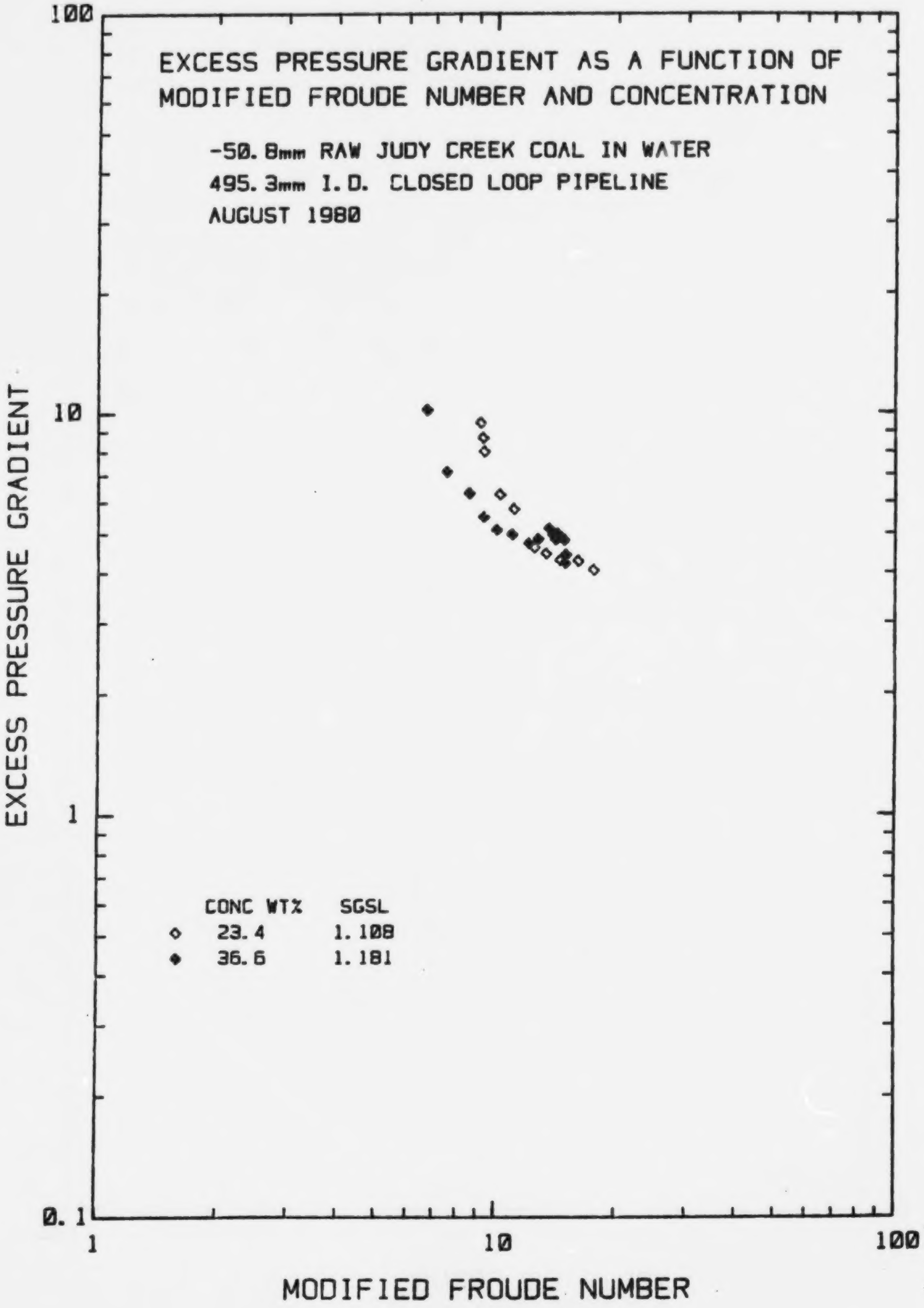

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm RAW JUDY CREEK COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
CONC WT% SGSL
◇ 23.4 1.108
◆ 36.6 1.181
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 79

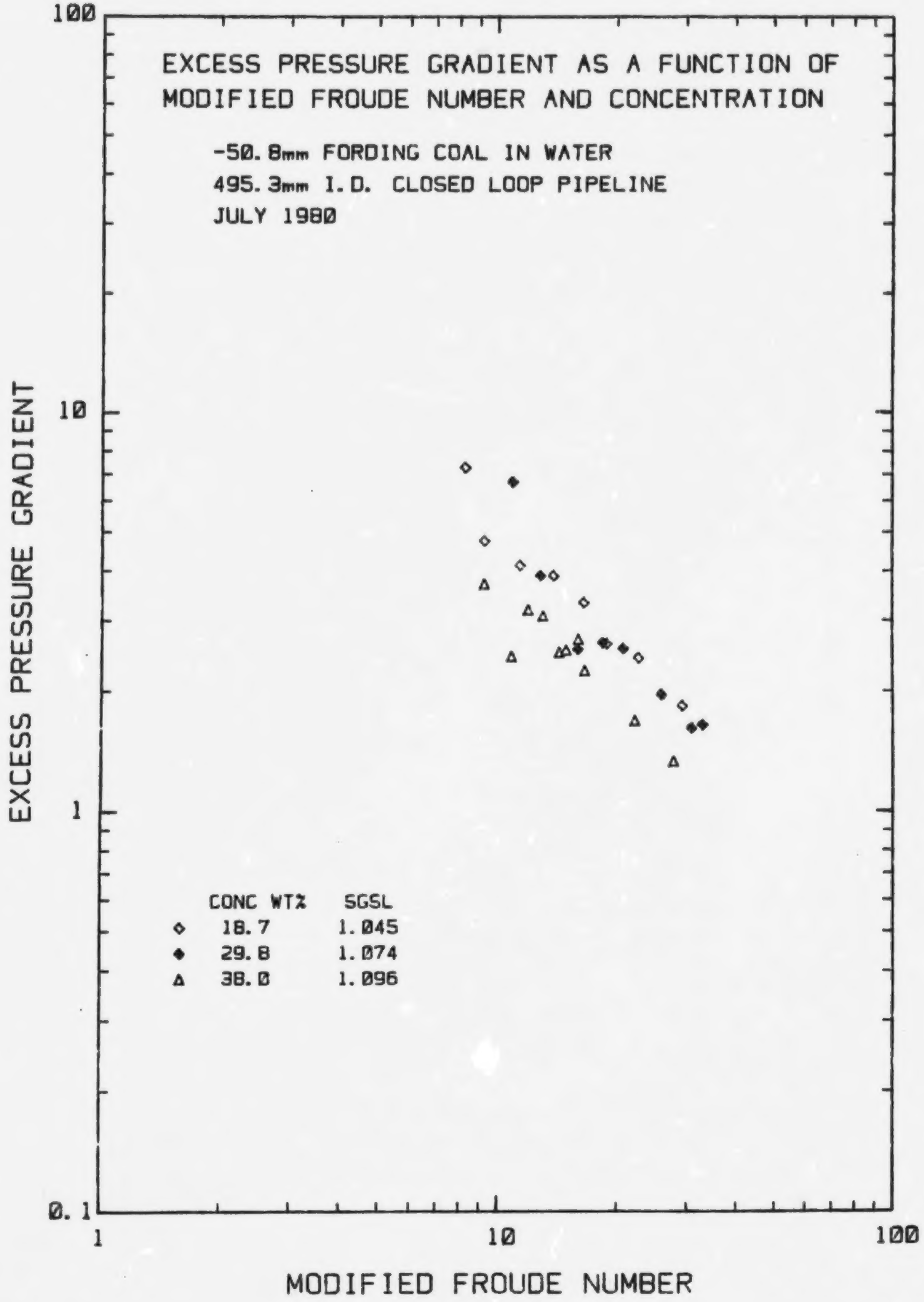

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm FORDING COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
JULY 1980
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER
CONC WT% SGSL
◇ 18.7 1.045
◆ 29.8 1.074
△ 38.0 1.096

Figure 80

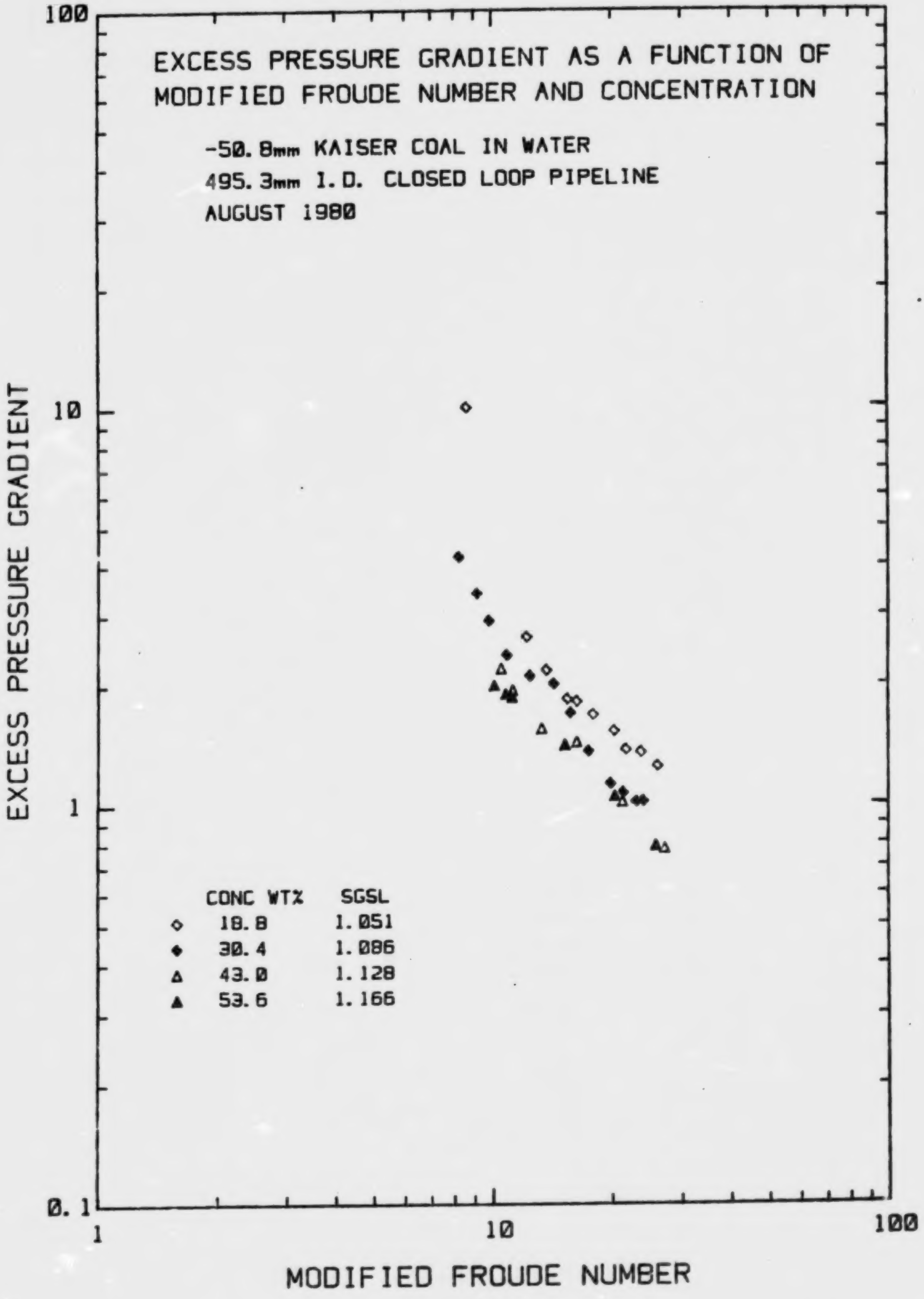

EXCESS PRESSURE GRADIENT AS A FUNCTION OF MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980
CONC WT% SGSL
◇ 18.8 1.051
◆ 30.4 1.086
△ 43.0 1.128
▲ 53.6 1.166
EXCESS PRESSURE GRADIENT
100
10
1
0.1
1
10
100
MODIFIED FROUDE NUMBER

Figure 81

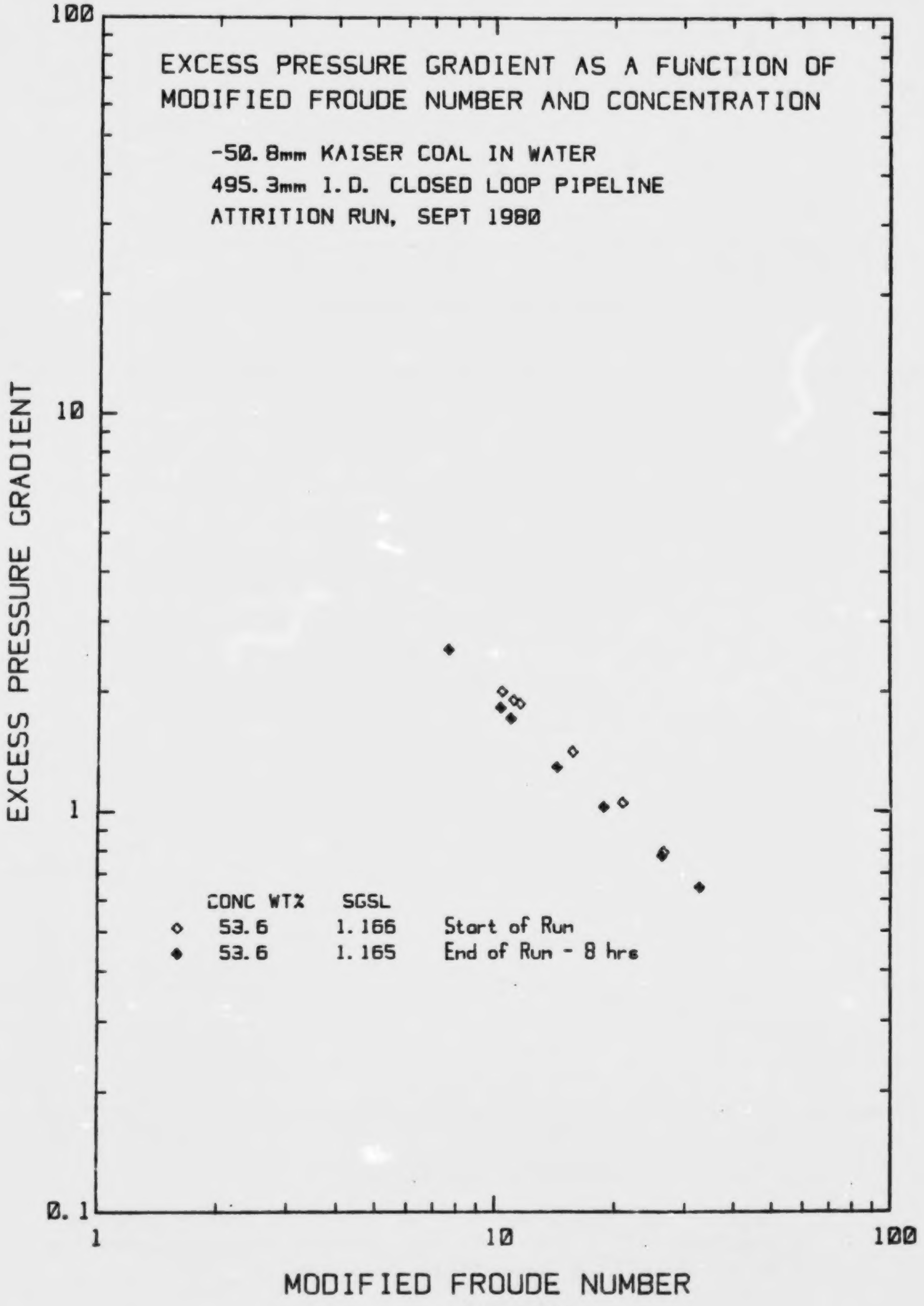
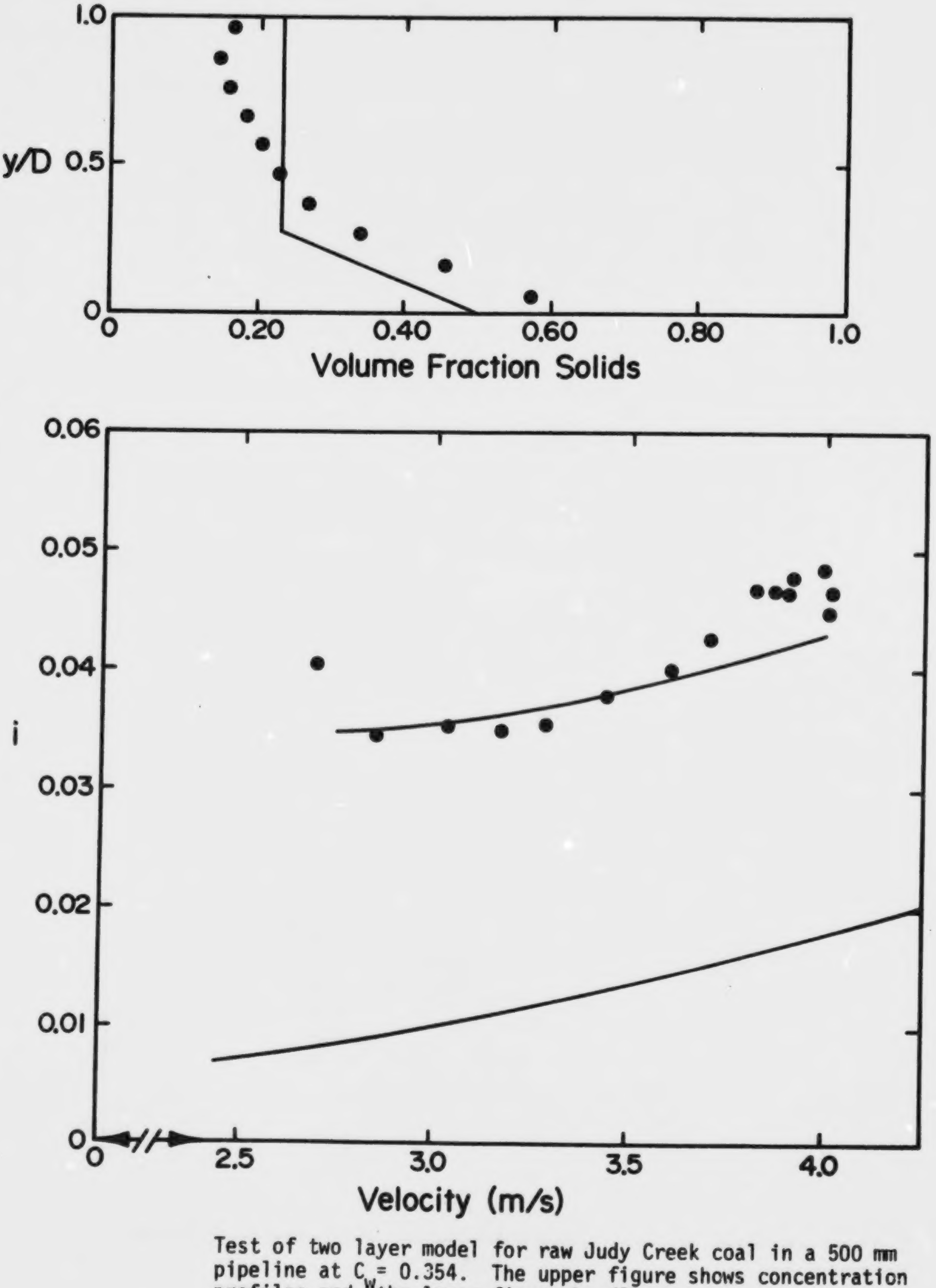
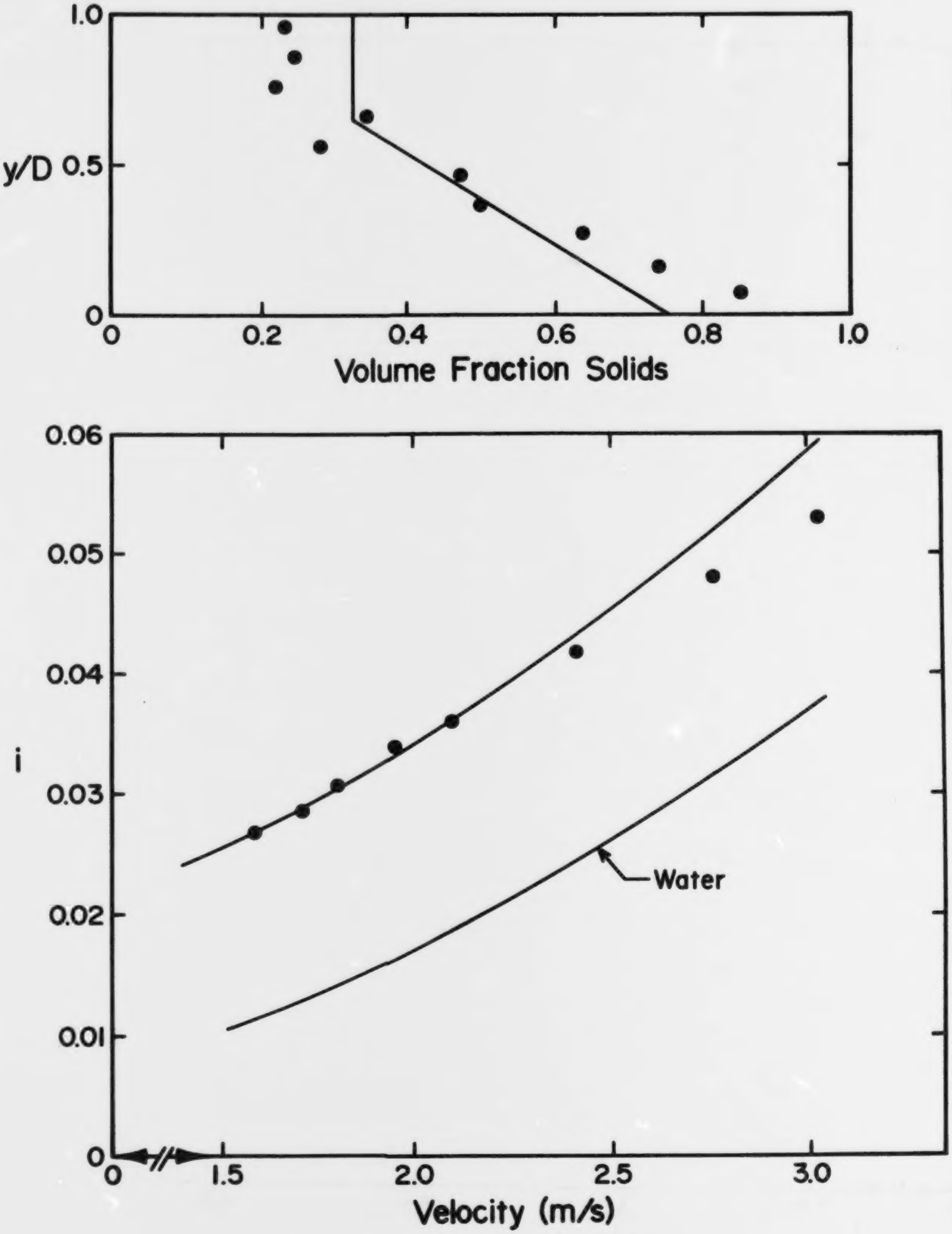

EXCESS PRESSURE GRADIENT AS A FUNCTION OF
MODIFIED FROUDE NUMBER AND CONCENTRATION
-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980
CONC WT% SGSL
◇ 53.6 1.166 Start of Run
◆ 53.6 1.165 End of Run - 8 hrs
100
10
1
0.1
1
10
100
EXCESS PRESSURE GRADIENT
MODIFIED FROUDE NUMBER

Figure 82



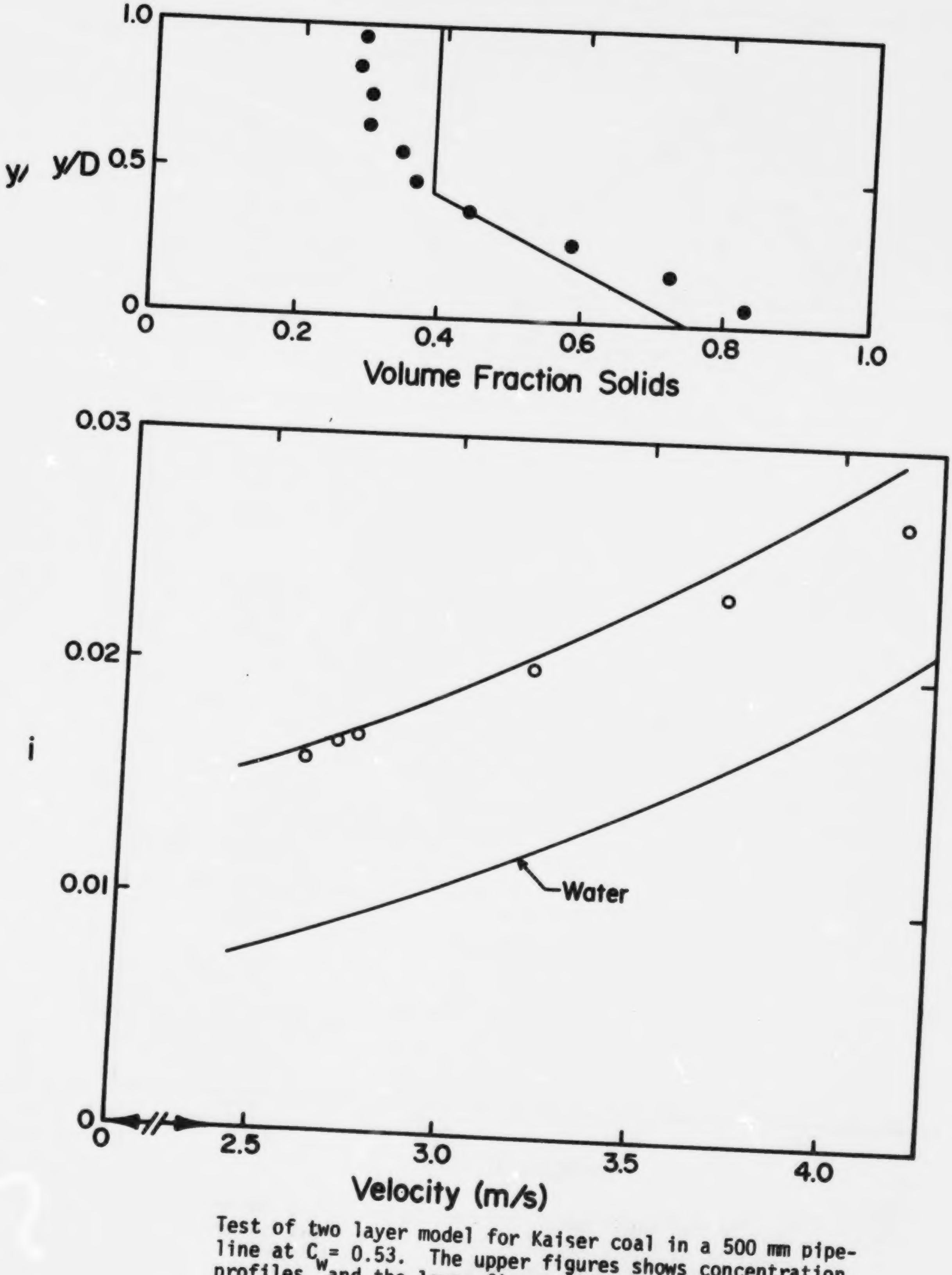
Test of two layer model for raw Judy Creek coal in a 500 mm pipeline at $C_w = 0.354$. The upper figure shows concentration profiles and the lower figure headlosses.

Figure 83



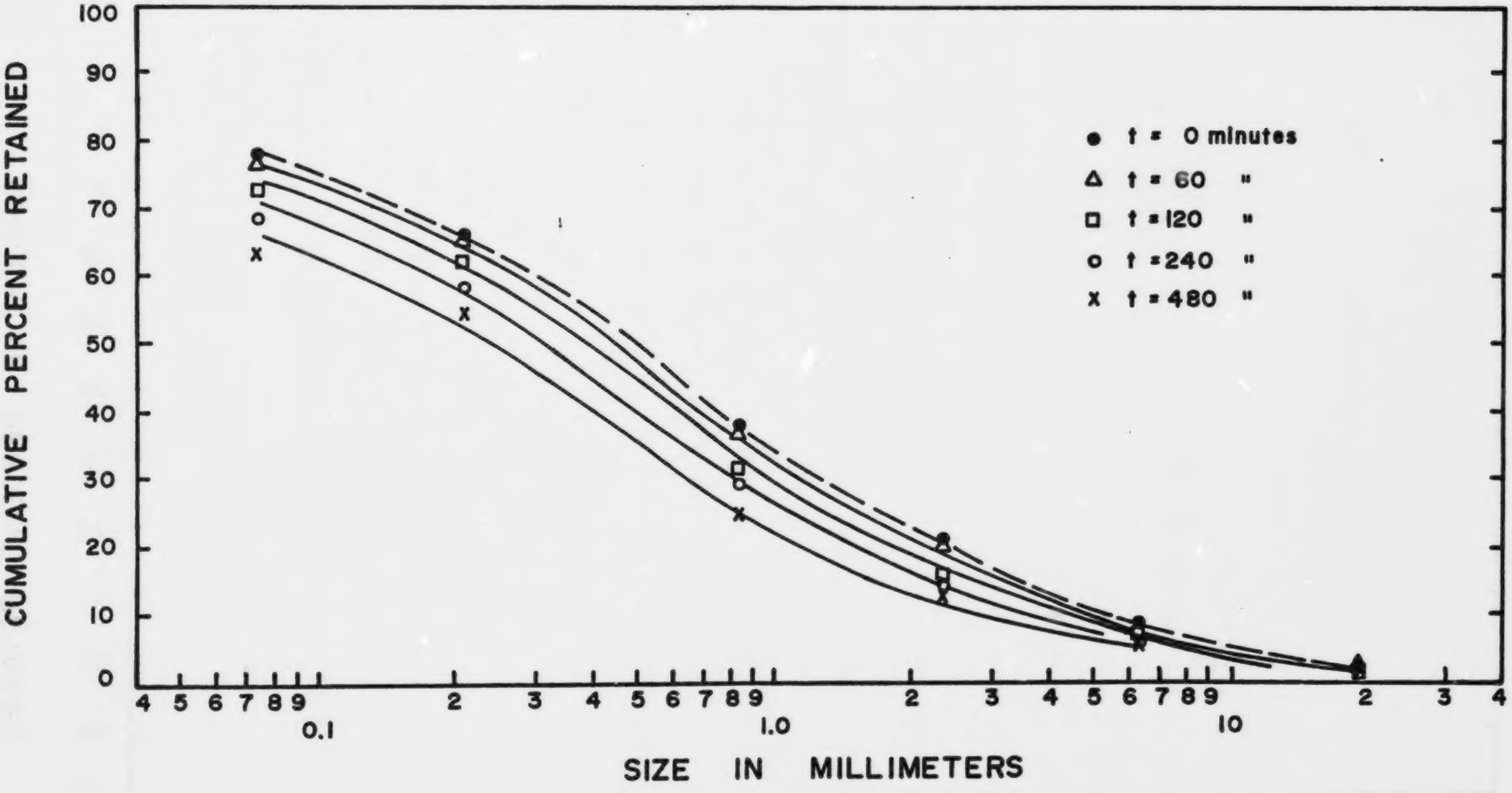
Test of two layer model for Fording coal in a 150 mm pipeline at $C_w = 0.51$. The upper figure shows concentration profiles and the lower figure headlosses.

Figure 84



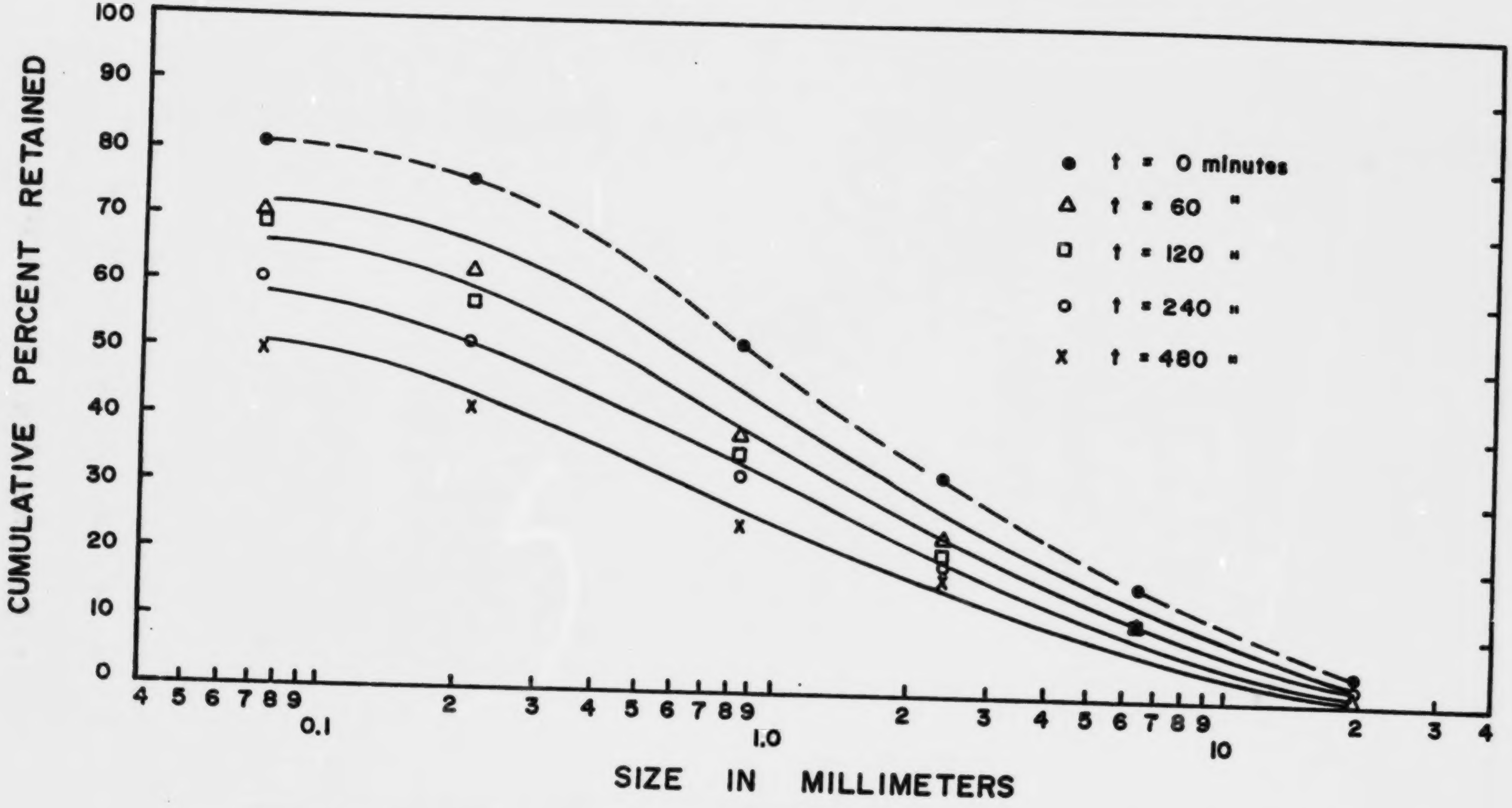
Test of two layer model for Kaiser coal in a 500 mm pipeline at $C_w = 0.53$. The upper figures shows concentration profiles and the lower figure headlosses.

Figure 85



Degradation Test results for Kaiser coal slurry in a 150 mm pipeline at $C_w = 0.53$.
The solid lines are computed from the Austin and Luckie model.

Figure 86



Degradation test results for Kaiser coal slurry in a 500 mm pipeline at $C_w = 0.53$.
The solid lines are computed from the Austin and Luckie model.

Figure 87

REFERENCES

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SYMBOLS

A - Cross sectional area of pipe

A_1 - Area occupied by suspended load material

A_2 - Area occupied by contact load material

$b_{i,j}$ - Fraction of particles from interval j falling into inverval i

c_1 or C_1 - Concentration of suspended solids

c_2 - Maximum concentration in lower layer

c_c - Local value of contact load

C_c - Mean value of contact load - $\frac{1}{A} \int c_c dA = C_t - C_1$

C_{vd} or C_v - Volume fraction solids in discharged mixture

C_{vt} or C_t - In-situ mean volume fraction solids

CONCWT or Cw- Solids concentration by weight

C_{Dm} or Cd - Mean particle drag coefficient

C_{Di} - Drag coefficient for particle of diameter, d_i

d_i - Screen opening

D - Inside pipe diameter

g - Gravitational acceleration

i - Headloss in metres of fluid per metre of pipe

i_f - Headloss of fluid in metres of fluid per metre of pipe

MB - Moving bed flow regime

MD - Moving dunes flow regime

PSD - Particle size distribution

S - Selection rate constant for particle degradation

SYMBOLS (cont'd)

S_1 - Perimeter of contact between the pipe wall and area 1

S_2 - Perimeter of contact between the pipe wall and area 2

S_{12} - Perimeter of contact between the areas 1 and 2

S_i - Selection rate constant for degradation of particles in interval i

S_s - Ratio of solid to carrier fluid specific gravity

SB - Stationary bed flow regime

SGSL - Specific gravity of slurry

t - Time

u^* - Friction velocity $= \sqrt{igD/4}$

V - Average velocity

V_1 - Average slurry velocity in zone of suspended solids

V_2 - Average slurry velocity in contact load zone

V_c - Critical deposition velocity

V_s - Velocity of contact load particles in lower layer

w_i - Weight fraction of particles in size interval i

W_i - Terminal falling velocity for particles of diameter d_i in the carrier fluid

y - Distance from the bottom of the pipe

y_1 - Distance from the bottom of the pipe to the interface between the suspended and contact load regions

η_s - Coefficient of sliding friction

μ_1 - Viscosity of slurry in suspended solid zone

μ_f - Viscosity of fluid

SYMBOLS (cont'd)

ρ_1 - Density of slurry in suspended solid zone

ρ_f - Density of fluid

ρ_s - Density of solid

τ_1 - Shear stress at wall in suspended solid zone

τ_2 - Shear stress at wall in contact load zone

τ_{12} - Interfacial shear stress

ϕ_t - Excess pressure gradient, $(i - i_f)/C_{vt} i_f$

ψ^{-1} - Modified Froude number, $v^2\sqrt{C_{Dm}}/gD\ (S_s-1)$

APPENDIX A

TABLES OF HEADLOSS AND PARTICLE SIZE DISTRIBUTION DATA

Note:

Concentration determinations for tests in the 50 mm diameter pipeline were made by taking full pipeline discharge samples. Therefore the concentrations reported on pages A2 to A9 are delivered concentrations. Concentration determinations for tests in the 100, 150, 250 and 500 mm diameter pipelines were made by weighing solids into pipeline loops of predetermined volumes. Hence the concentrations reported on pages A10 to A55 are in situ concentrations.

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-14 mesh RAW JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
APRIL 1980

Solids Moisture=21.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	44	74	105	149	210	297	420	595	841	1190	1680	2380
PSD1	15.4	17.2	19.2	22.3	27.0	34.4	47.2	63.8	86.0	94.9	96.8	98.5
PSD2	17.9	19.7	21.8	24.9	29.6	37.0	49.6	66.3	88.1	95.8	97.7	99.1
PSD3	16.3	17.9	19.7	22.7	27.3	34.9	48.7	66.2	88.5	95.4	97.1	98.4
PSD4	14.0	16.1	18.7	22.7	28.7	37.9	52.6	70.5	90.9	96.9	98.2	99.3
PSD5	16.3	18.4	20 9	24.7	30.4	39.1	53.2	70.4	91.2	97.2	98.4	99.3
PSD6	17.6	20.2	23.1	27.3	33.5	42.6	56.8	73.1	94.4	97.3	98.4	99.2
PSD7	20.3	22.8	26.0	29.8	35.9	44.7	58.0	73.6	91.5	96.7	98.1	99.1

Average CONCWT= 0.0%   SGSL=0.999   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.05	16.17	0.0		
2.80	14.07	0.0		
2.50	11.23	0.0		
2.13	8.54	0.0		
1.86	6.65	0.0		
1.52	4.41	0.0		
1.22	2.74	0.0		
0.82	1.56	0.0		

Average CONCWT=23.2%   SGSL=1.107   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.05	17.59	23.5		PSD1
2.68	15.21	24.1		
2.38	11.76	23.2		
2.10	9.66	23.3		
1.83	7.67	23.4		
1.52	6.15	23.4		
1.03	6.14	24.4		
1.04	6.75	22.3	SB	PSD2

Average CONCWT=30.4%   SGSL=1.146   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.01	18.45	29.9		
2.71	15.46	31.0		
2.41	12.79	31.5		
2.13	10.06	31.0		
1.80	8.14	30.9		
1.59	6.97	29.3		
1.34	5.86	29.6		
1.26	5.86	29.9	SB	PSD3

Average CONCWT=37.3%   SGSL=1.185   Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	19.83	37.1		
2.71	16.14	37.2		
2.41	12.62	36.7		
2.10	10.31	35.6		
1.83	8.49	37.4		
1.62	7.96	37.6	MB	
1.40	9.10	39.3	SB	
1.40	9.10	39.3	SB	PSD4

Average CONCWT=42.5%   SGSL=1.217   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	19.93	42.3		
3.02	20.00	42.2		
2.74	17.10	42.7		
2.44	14.30	43.4		
2.16	11.69	43.3		
1.83	10.27	42.0		
1.80	9.20	42.2		
1.62	10.98	44.5	SB	PSD5

Average CONCWT=47.9%   SGSL=1.252   Temp=15C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	22.49	47.2		
3.02	22.60	47.3		
2.77	19.70	47.5		
2.44	16.30	48.5		
2.29	14.70	47.5		
2.13	13.20	47.7		
1.95	11.70	49.2		
1.80	10.80	49.0		
1.68	10.61	49.4	SB	PSD6

Average CONCWT=50.4%   SGSL=1.268   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.08	27.12	50.8		
2.71	22.14	49.7		
2.46	18.55	51.3		
2.19	15.14	50.6		
1.95	13.58	50.4		
1.83	11.94	50.8		
1.66	10.45	51.4	MD	
1.47	10.02	50.7	MD	
1.30	11.16	51.4	MD	
1.23	11.94	51.2	SB	PSD7

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-14 mesh WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980

Solids Moisture=20.0%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	44	74	105	149	210	297	420	595	841	1190	1680	2380
PSD1	11.3	12.1	13.3	15.4	19.0	25.1	36.2	52.4	79.0	94.7	98.3	100.0
PSD2	9.0	9.9	11.2	13.5	17.2	23.7	35.7	53.0	80.6	95.3	98.6	100.0
PSD3	10.5	11.3	12.7	15.0	18.9	25.6	37.9	55.3	82.5	96.1	99.1	100.0
PSD4	9.0	10.0	11.5	14.0	18.2	25.0	37.2	54.7	83.1	95.9	98.8	100.0
PSD5	11.2	13.1	15.7	19.9	26.1	34.9	49.1	65.1	87.3	96.4	99.1	100.0
PSD6	8.6	10.8	13.5	17.7	23.8	32.7	46.6	63.9	86.5	96.1	99.1	100.0

Average CONCWT= 0.0%   SGSL=1.000   Temp=11C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
2.99	16.56	0.0		
2.71	13.61	0.0		
2.38	10.84	0.0		
2.10	8.57	0.0		
1.80	6.40	0.0		
1.49	4.62	0.0		
1.19	3.06	0.0		
0.88	1.82	0.0		

Average CONCWT=22.7%   SGSL=1.096   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.08	17.31	23.6		PSD1
2.68	13.72	21.8		
2.41	11.37	22.1		
2.10	9.17	22.6		
1.77	7.71	23.0		
1.43	7.32	22.9		
1.34	7.49	22.9		
1.19	6.61	21.0	MD	
1.16	7.75	22.9	MD	
1.04	9.52	22.5	SB	PSD2

Average CONCWT=28.9%   SGSL=1.126   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.05	17.38	29.0		
2.71	14.25	29.5		
2.41	11.62	28.0		
2.13	3.77	28.8		
1.77	8.57	29.0		
1.65	8.28	29.9		
1.52	3.14	23.4	MD	
1.37	8.42	28.9	MD	
1.19	8.74	29.3	MB	
1.01	9.20	29.9	MB	
1.04	10.56	27.6	SB	PSD3

Average CONCWT=35.2%   SGSL=1.159   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	16.91	35.4		
2.77	14.57	35.9		
2.47	12.26	36.0		
2.13	10.48	36.1		
1.89	8.78	34.6		
1.68	8.89	35.5		
1.46	8.60	34.6		
1.40	8.54	34.2	MD	
1.19	8.74	35.0	MB	
1.04	8.74	34.7	MB	
0.91	10.27	34.9	SB	PSD4

Average CONCWT=45.1%   SGSL=1.213   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.05	21.70	45.0		
2.77	19.60	44.3		
2.38	16.70	44.6		
2.13	15.30	45.3		
1.77	13.20	45.8		
1.68	12.50	45.2		
1.55	13.10	46.2		
1.37	10.20	45.1		
1.19	9.60	45.1	MD	
1.10	9.50	45.6	MD	
0.94	8.30	44.3	MD	
0.79	9.00	45.1	MB	
0.61	8.20	44.9	MB	PSD5

A7

Average CONCWT=46.7%   SGSL=1.223   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	23.60	46.4		
2.71	20.80	46.4		
2.41	18.10	46.2		
2.07	16.30	47.5		
1.93	15.60	47.4		
1.58	12.70	46.9		
1.25	10.90	46.6		
0.94	10.20	47.3	MB	
0.70	8.40	45.4	MB	PSD6

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-8 MESH WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980

Solids Moisture=20.0%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	1190	2380
PSD1	6.1	12.4	24.8	54.2	78.1	100.0
PSD2	12.9	22.5	37.7	66.2	86.5	100.0
PSD3	14.0	22.0	36.5	65.9	86.6	100.0
PSD4	6.6	13.5	26.4	55.5	79.2	100.0
PSD5	4.9	10.4	21.8	51.1	76.8	100.0

Average CONCWT= 0.0%   SGSL=0.999   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.01	16.60	0.0		
2.71	13.47	0.0		
2.42	10.98	0.0		
2.12	8.67	0.0		
1.80	6.22	0.0		
1.48	4.58	0.0		
1.19	3.16	0.0		
0.88	1.92	0.0		

Average CONCWT=22.2%   SGSL=1.094   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.08	17.95	22.4		PSD1
2.74	14.93	23.2		
2.38	12.01	21.7		
2.10	10.41	22.8		
1.95	9.45	22.4		
1.80	8.99	22.1		
1.68	8.49	22.4		
1.52	8.26	21.8		
1.37	8.07	21.9	MD	
1.19	7.68	21.9	MD	
1.04	7.46	21.5	MD	
0.85	8.10	21.1	SB	

Average CONCWT=30.1%   SGSL=1.132   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.02	18.94	29.8		PSD2
2.71	15.60	30.2		
2.44	12.60	30.5		
2.13	10.48	29.7		
1.80	9.09	30.8		
1.52	7.96	29.7		
1.19	7.99	30.0		
0.88	8.10	29.5	MD	
0.76	9.17	30.4	SB	PSD3

Average CONCWT=35.3%   SGSL=1.159   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	DRY SOLIDS CONCWT%	FLOW REGIME	PSD NUMBER
3.09	18.52	34.8		PSD4
2.78	16.24	35.5		
2.46	14.39	36.4		
2.14	11.59	34.7		
1.81	10.59	34.8		
1.69	10.38	35.8		
1.50	9.88	34.4		
1.50	10.06	36.5		
1.33	9.67	35.7		
1.22	9.52	34.9	MD	
1.10	9.60	35.0	MD	
0.90	9.88	34.7	MD	
0.75	10.34	35.0	MB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-8 mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980

Solids Moisture=26.0%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	44	74	105	149	210	297	420	595	841	1190	1680	2380
PSD1	5.6	7.1	9.1	12.3	16.9	23.4	33.0	44.1	59.3	79.1	95.0	99.8
PSD2	3.5	11.9	14.7	19.0	25.0	33.1	44.2	56.0	70.2	85.7	96.4	99.0
PSD3	11.5	13.4	15.7	19.3	24.4	31.3	40.9	51.3	64.9	81.8	95.8	99.5
PSD4	8.9	10.6	12.6	15.7	20.1	26.4	36.0	47.1	62.0	81.9	96.5	99.9
PSD5	11.5	13.1	14.9	17.6	21.5	27.2	36.5	47.5	62.1	80.8	96.2	99.8

CONCWT= 0.0% SGSL=1.000 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	6.41		
2.74	5.29		
2.44	4.22		
2.13	3.32		
1.83	2.55		
1.52	1.80		
1.22	1.22		
0.91	0.71		
0.61	0.30		

CONCWT=22.5% SGSL=1.096 Temp= 8C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	7.53		PSD1
2.74	6.56		
2.44	5.82		
2.13	5.16		
1.83	4.60		
1.65	4.07		
1.52	3.93	MD	
1.40	4.20	MD	
1.28	4.12	MD	
1.10	3.96	SB	
1.16	3.99	SB	PSD2

CONCWT=35.4%   SGSL=1.161   Temp= 8C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	8.03		
2.74	7.31		
2.44	6.99		
2.13	6.49		
1.80	5.53		
1.65	5.44		
1.52	5.26	MD	
1.40	5.50	MB	
1.22	6.09	SB	PSD3

CONCWT=47.0%   SGSL=1.225   Temp= 6C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	8.54		
2.74	8.00		
2.44	7.44		
2.13	7.18		
1.89	6.96		
1.68	6.80		
1.52	6.96		
1.40	7.44		
1.22	7.77		
1.10	8.58	SB	PSD4

CONCWT=57.4%   SGSL=1.290   Temp= 5C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	10.13		
2.74	9.09		
2.44	8.92		
2.13	8.00		
1.83	7.36		
1.68	7.17		
1.52	6.97		
1.37	6.80		
1.22	6.76		
1.10	6.70		
1.04	6.76	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm RAW JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980

Solids Moisture=21.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	105	149	210	420	841	1190	1680	2380	3360	4760	9520
PSD1	15.3	17.2	19.9	23.4	35.0	52.1	63.1	72.6	82.2	90.7	93.9	100.0
PSD2	18.4	19.9	22.0	25.0	35.0	50.2	60.6	70.2	80.6	90.9	96.0	100.0
PSD3	20.7	22.3	24.5	27.6	37.3	52.9	63.7	73.7	83.6	91.9	95.3	100.0
PSD4	21.9	23.4	25.5	28.3	38.0	53.6	64.1	73.8	83.5	92.3	96.9	100.0
PSD5	27.0	28.0	29.4	31.4	38.3	51.2	60.9	70.7	81.4	91.5	95.7	100.0

CONCWT= 0.0%   SGSL=0.999   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	6.30		
2.74	5.23		
2.44	4.22		
2.13	3.41		
1.83	2.52		
1.52	1.91		
1.22	1.20		
0.91	0.72		

CONCWT=23.1%   SGSL=1.107   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.20	9.33		PSD1
3.06	8.85		
2.74	7.79		
2.44	6.80		
2.13	6.01		
1.84	5.37		
1.65	4.99		
1.49	4.79	MB	
1.34	4.73	MB	
1.22	4.99	SB	PSD2

CONCWT=37.1%   SGSL=1.184   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.26	10.71		
3.06	10.15		
2.74	9.09		
2.38	8.03		
2.07	7.13		
1.83	6.44		
1.65	6.08	MD	
1.51	5.98	MB	
1.37	5.90	MB	
1.19	5.90	SB	PSD3

CONCWT=47.7%   SGSL=1.251   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.23	11.69		
3.05	11.29		
2.74	10.44		
2.44	9.49		
2.13	8.66		
1.92	8.13		
1.62	7.68	MD	
1.34	6.96	MB	
1.25	6.83	SB	PSD4

CONCWT=57.9%   SGSL=1.322   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
2.93	11.81		
2.74	11.25		
2.41	10.28		
2.16	9.51		
1.80	8.78		
1.65	8.54		
1.49	8.21	MB	
1.28	8.00	MB	
1.22	7.93	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980

Solids Moisture=26.4%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	105	149	210	420	841	1190	1680	2380	3360	4760	9518
PSD1	13.6	15.6	18.5	22.5	35.1	53.6	66.0	76.5	86.1	94.7	97.8	100.0
PSD2	12.1	13.9	16.5	19.9	30.7	48.6	61.6	72.6	83.1	91.7	95.1	100.0
PSD3	15.7	16.7	18.4	21.0	28.9	43.7	56.2	67.7	79.5	91.6	96.6	100.0
PSD4	10.8	12.3	14.4	17.2	26.6	43.0	55.4	67.4	80.1	91.8	96.7	100.0
PSD5	14.0	15.1	16.7	19.1	27.4	43.4	55.7	67.3	79.1	89.9	94.9	100.0

CONCWT= 0.0%   SGSL=0.999   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	6.12		
2.74	5.13		
2.44	4.06		
2.13	3.21		
1.83	2.44		
1.52	1.72		
1.22	1.17		

CONCWT=21.5%   SGSL=1.091   Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.34	8.72		PSD1
3.02	7.49		
2.74	6.68		
2.42	5.77		
2.27	5.40		
2.16	5.11		
1.93	4.77		
1.84	4.46		
1.71	4.18		
1.55	3.95	MB	
1.34	3.78	SB	PSD2

CONCWT=34.0%   SGSL=1.152   Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.26	9.65		PSD3
3.05	8.88		
2.76	7.92		
2.44	7.09		
2.10	6.20		
1.86	5.61		
1.69	5.18		
1.54	4.95		
1.40	4.83	MD	
1.28	4.58	MB	
1.19	4.99	SB	

CONCWT=45.2%   SGSL=1.214   Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.03	9.97		PSD4
2.74	9.31		
2.47	8.77		
2.13	8.00		
1.83	7.12		
1.58	6.75		
1.37	6.56		
1.22	6.41	MB	
1.10	7.93	SB	

CONCWT=55.3%   SGSL=1.276   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.11	10.82		PSD5
2.71	10.15		
2.38	9.60		
2.04	9.01		
1.77	8.77		
1.52	8.30		
1.34	7.92	MB	
1.10	8.26	SB	

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm +8mesh WASHED JUDY CREEK COAL IN WATER
107.5mm I.D. CLOSED LOOP PIPELINE
APRIL 1980

Solids Moisture=20.0%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	1190	2380	6730
PSD1	6.2	9.3	13.4	22.1	30.8	67.0	100.0
PSD2	11.3	14.1	18.0	26.1	34.6	71.4	100.0
PSD3	13.2	16.0	20.1	28.6	37.7	74.3	100.0
PSD4	12.8	15.4	19.6	28.7	38.0	74.6	100.0

CONCWT= 0.0%   SGSL=1.000   Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	6.41		
2.74	5.29		
2.44	4.22		
2.13	3.32		
1.83	2.55		
1.52	1.80		
1.22	1.22		
0.91	0.71		
0.61	0.30		

CONCWT=22.5%   SGSL=1.096   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.11	10.93		PSD1
2.87	9.99		
2.76	9.65		
2.44	8.38		
2.19	7.64		
1.95	6.99		
1.68	6.36		
1.49	6.04		
1.40	5.88	MD	
1.22	5.45	MD	
1.43	5 27	MD	
1.34	5.13	MB	
0.91	4.87	MB	
0.85	4.87	SB	PSD2

CONCWT=35.4%   SGSL=1.160   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.05	12.74		
2.74	12.13		
2.50	11.46		
2.16	10.48		
1.83	9.27		
1.65	8.88		
1.46	8.48		
1.31	8.38		
1.22	8.21	MD	
1.10	8.06	MB	
0.91	7.95	SB	PSD3

CONCWT=47.0%   SGSL=1.225   Temp=11C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.11	15.10		
2.71	13.32		
2.41	12.86		
2.13	12.12		
1.83	11.49		
1.52	10.77		
1.40	10.61		
1.22	10.20		
1.07	10.07		
0.91	10.20	MD	
0.85	9.97	MB	
0.79	10.00	SB	PSD4

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980

Solids Moisture=22.5%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	1190	2380	9510
PSD1	20.3	26.9	35.2	47.7	54.3	79.2	100.0
PSD2	17.5	27.2	39.3	59.9	69.7	87.9	100.0
PSD3	20.7	28.8	40.0	57.5	66.5	87.7	100.0
PSD4	17.4	25.1	35.2	53.8	64.3	86.3	100.0
PSD5	23.7	28.5	34.7	44.2	52.0	75.6	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.09	3.96	0.57		
2.74	3.25	0.96		
2.44	2.60	0.48		
2.13	2.10	0.37		
1.84	1.60	0.38		
1.54	1.20	0.37		
1.22	0.84	0.41		
0.94	0.56	0.16		
0.62	0.34	0.32		

CONCWT=23.4%   SGSL=1.108   Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.04	6.35	0.40		PSD1
2.79	5.70	0.50		
2.43	4.36	0.82		
2.16	4.56	1.02		
1.97	4.28	0.86		
1.83	4.17	0.93		
1.69	4.00	0.85	MD	
1.54	3.90	0.83	MD	
1.40	4.28	0.79	MD	
1.43	4.36	0.88	MD	
1.28	4.00	0.99	SB	PSD2

CONCWT=36.6%   SGSL=1.181   Temp=18C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.06	8.10	0.10		
2.76	7.42	0.48		
2.49	6.80	0.54		
2.12	6.49	0.27		
1.97	6.27	0.53		
1.82	6.10	0.52	MD	
1.68	6.14	0.69	MD	
1.54	6.34	0.62	MD	
1.38	7.03	0.58	MD	
1.31	5.97	0.73	SB	PSD3

CONCWT=48.2%   SGSL=1.253   Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.10	9.68	0.27		
2.82	8.88	0.60		
2.41	7.80	0.64		
2.24	7.65	0.55		
2.00	7.42	0.53		
1.76	8.10	0.39		
1.67	8.50	0.22	MD	
1.48	8.31	0.06	MD	
1.37	8.04	0.45	MD	
1.32	9.06	0.79	MD	
1.24	10.12	1.11	SB	PSD4

CONCWT=58.6%   SGSL=1.326   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.03	12.86	0.54		
2.72	11.81	0.60		
2.39	10.40	0.40		
2.09	9.66	0.63		
1.97	9.36	0.63		
1.74	9.40	0.71		
1.65	9.22	0.96		
1.42	8.71	0.76	MD	
1.19	9.84	0.77	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm WASHED JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MARCH 1980

Solids Moisture=27.4%
Specific Gravity of Dried Solids=1.643

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	1190	2380	6730
PSD1	11.5	24.4	65.4	74.4	91.0	100.0
PSD2	9.3	23.3	67.4	75.6	93.0	100.0
PSD3	6.5	19.5	61.8	73.2	91.0	99.2
PSD4	17.1	24.1	52.7	61.6	84.5	98.4
PSD5	10.8	18.3	52.6	62.9	86.9	99.1

CONCWT= 0.0%   SGSL=1.000   Temp= 6C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.23	4.39		
3.05	3.95		
2.65	3.06		
2.42	2.57		
2.10	2.04		
1.80	1.54		
1.54	1.13		
1.22	0.76		
0.91	0.46		

CONCWT=22.5%   SGSL=1.096   Temp=10C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.35	6.04		PSD1
3.05	5.46		
2.74	4.82		
2.44	4.29		
2.29	3.95		
2.13	3.76		
1.98	3.51		
1.83	3.39	MD	
1.65	3.20	MD	
1.52	3.23	MD	
1.40	3.26	SB	PSD2

CONCWT=35.3% SGSL=1.160 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.34	7.52		
3.05	7.09		
2.73	6.22		
2.41	5.58		
2.06	5.17		
1.83	4.98		
1.52	5.47	MB	
1.68	5.31	MD	
1.52	5.40	SB	PSD3

CONCWT=47.0% SGSL=1.225 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.41	9.53		
3.05	8.82		
2.83	8.36		
2.44	8.35		
2.23	8.09		
2.13	7.76		
1.96	7.36		
1.83	7.08		
1.68	7.07		
1.52	7.02	MD	
1.34	7.13	MD	
1.19	7.68	SB	PSD4

CONCWT=57.4% SGSL=1.289 Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.29	9.64		
3.05	9.28		
2.74	8.91		
2.44	8.74		
2.13	8.63		
1.83	8.58		
1.65	8.58		
1.52	8.54		
1.37	8.09	MD	
1.13	8.31	MB	
1.07	8.25	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-9.5mm +8 mesh RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980

Solids Moisture=19.3%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	1190	2380	9510
PSD1	6.4	13.4	24.6	41.3	51.1	77.6	100.0
PSD2	18.9	25.3	35.0	47.8	54.9	78.5	100.0
PSD3	21.3	26.4	35.4	49.4	58.1	80.2	100.0
PSD4	16.0	20.3	29.1	46.0	54.6	79.7	100.0

CONCWT= 0.0% SGSL=0.999 Temp=14C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.06	3.90	1.41		
2.75	3.21	1.00		
2.44	2.59	1.30		
2.14	2.02	1.00		
1.83	1.53	1.20		
1.56	1.14	1.06		
1.25	0.75	0.95		
0.93	0.44	0.72		

CONCWT=23.4% SGSL=1.108 Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.22	8.64	0.49		
3.05	8.22	0.45		PSD1
2.72	7.54	0.64		
2.47	6.37	0.96		
2.17	6.41	1.23		
1.99	6.11	1.12		
1.83	5.94	1.11		
1.73	5.78	1.00	MD	
1.54	5.52	1.23	MD	
1.40	4.66	0.98	MD	
1.26	5.32	0.66	SB	PSD2

CONCWT=36.6% SGSL=1.181 Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	 RMS m/100m	FLOW REGIME	PSD NUMBER
3.21	12.62	0.51		
3.07	12.10	0.49		
2.74	10.93	0.84		
2.45	10.29	1.12		
2.17	10.05	1.27		
2.02	9.72	1.41		
1.85	9.45	1.13		
1.70	9.09	1.26		
1.57	9.26	1.22		
1.43	8.42	1.03	MD	
1.30	8.16	1.06	MD	
1.07	7.61	0.83	SB	PSD3

CONCWT=48.2% SGSL=1.254 Temp=16C

VELOCITY m/sec	HEADLOSS MEAN m/100m	 RMS m/100m	FLOW REGIME	PSD NUMBER
3.24	16.07	0.90		
3.09	15.43	0.73		
2.75	14.20	1.08		
2.43	13.28	1.61		
2.18	12.82	1.30		
2.04	12.49	1.34		
1.84	11.49	1.39		
1.71	11.84	1.26		
1.55	10.40	1.28		
1.48	10.84	1.91		
1.32	10.13	1.83		
1.19	8.73	1.64	MD	
1.19	8.79	2.08	MD	
1.00	9.19	1.95	SB	PSD4

CONCWT=58.6%   SGSL=1.326   Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.02	17.04	0.42		
2.73	15.95	0.50		
2.44	15.25	0.76		
2.10	14.57	0.96		
1.97	14.31	1.13		
1.81	13.96	0.94		
1.66	13.50	0.84		
1.54	13.16	0.81		
1.40	12.74	0.62		
1.19	12.28	0.13		
1.08	11.75	0.49	MD	
0.91	11.27	0.50	MD	
0.68	10.89	0.29	MB	
0.59	10.62	0.44	SB	

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980

Solids Moisture=23.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	2380	6350	50800
PSD1	20.5	26.3	36.4	49.4	78.3	94.2	100.0
PSD2	32.1	37.7	47.2	58.5	83.0	96.2	100.0
PSD3	12.7	19.6	30.0	42.6	73.6	93.1	100.0
PSD4	7.3	12.7	24.4	38.8	73.0	92.8	100.0
PSD5	18.0	24.1	33.9	47.5	75.1	91.9	100.0

CONCWT= 0.0%   SGSL=0.999   Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.02	4.04	0.69		
2.97	3.96	0.71		
2.73	3.37	1.14		
2.44	2.79	1.39		
2.08	2.09	1.41		
1.79	1.60	1.12		
1.51	1.19	0.86		
1.23	0.85	0.59		
0.94	0.56	0.55		

CONCWT=23.4%   SGSL=1.107   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.01	6.14	0.96		PSD1
2.76	5.59	1.17		
2.37	4.80	1.61		
2.13	4.37	2.12		
1.85	3.91	1.51		
1.68	3.77	1.51		
1.56	3.53	1.55		
1.43	3.34	2.28	MD	
1.42	3.26	1.48	MD	
1.05	2.74	5.71	SB	PSD2

CONCWT=36.8%   SGSL=1.180   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.03	8.00	1.11		
2.70	7.37	1.31		
2.45	6.83	1.51		
2.17	6.26	1.85		
1.89	5.67	1.79		
1.73	5.51	1.63	MD	PSD3

CONCWT=48.2%   SGSL=1.253   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.04	9.97	0.86		
2.73	9.08	0.48		
2.45	3.36	0.49		
2.14	7.66	0.46		
1.98	7.36	0.28		
1.87	7.12	0.92		
1.68	6.98	0.91		
1.63	7.07	2.53		
1.55	6.83	1.27	MD	
1.38	6.66	1.37	SB	PSD4

CONCWT=58.6%   SGSL=1.326   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.09	12.33	0.87		
2.76	11.14	0.87		
2.47	10.23	0.25		
2.55	10.25	0.39		
2.06	9.02	1.71		
1.83	8.57	1.99		
1.66	7.84	2.78		
1.59	7.72	2.58		
1.42	7.52	2.87		
1.21	7.24	6.71		PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, JUNE 1980

Solids Moisture=23.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	2380	6350	50800
PSD1	18.0	24.1	33.9	47.5	75.1	91.9	100.0
PSD2	26.0	32.1	39.7	50.3	76.0	92.9	100.0
PSD3	28.9	35.7	44.4	55.3	82.3	95.5	100.0
PSD4	34.4	40.2	47.7	55.4	80.0	94.5	100.0

CONCWT= 0.0%   SGSL=0.999   Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.02	4.04	0.69		
2.97	3.96	0.71		
2.73	3.37	1.14		
2.44	2.79	1.39		
2.03	2.09	1.41		
1.79	1.60	1.12		
1.51	1.19	0.86		
1.23	0.85	0.59		
0.94	0.56	0.55		

CONCWT=58.6%   SGSL=1.326   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.09	12.33	0.87		
2.76	11.14	0.87		
2.47	10.23	0.25		
2.55	10.25	0.39		
2.06	9.02	1.71		
1.83	8.57	1.99		
1.66	7.84	2.78		
1.58	7.72	2.58		
1.42	7.49	2.87		
1.21	7.24	6.71		PSD1

CONCWT-58.6%   SGSL=1.326   Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
2.95	9.89	0.36		PSD4
2.73	9.02	0.08		
2.36	7.58	0.11		
2.05	6.45	0.22		
1.77	5.60	0.58		
1.70	5.41	0.83	MD	
1.50	4.81	0.84	MD	
1.37	4.46	0.83	MD	
1.17	3.77	0.52	MB	
1.01	3.42	0.52	SB	

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980

Solids Moisture= 7.8%
Specific Gravity of Dried Solids=1.307

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	2380	6350	50800
PSD1	10.7	21.9	35.7	46.4	62.0	77.7	100.0
PSD2	16.1	30.6	44.9	54.5	69.9	84.8	100.0
PSD3	23.1	36.1	48.2	56.8	70.6	83.6	100.0
PSD4	24.5	36.1	51.5	61.3	74.7	85.9	100.0
PSD5	24.5	37.3	49.4	58.1	70.9	83.8	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=23C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN m/100m	RMS m/100m	REGIME	NUMBER
3.04	3.78	0.89		
2.71	3.05	0.92		
2.40	2.44	0.87		
2.13	1.95	1.36		
1.83	1.43	0.94		
1.55	1.06	0.73		
1.23	0.66	0.69		
0.92	0.41	0.52		

CONCWT=18.6%   SGSL=1.044   Temp=21C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN m/100m	RMS m/100m	REGIME	NUMBER
3.01	4.19	0.37		PSD1
2.72	3.54	0.82		
2.38	2.92	1.36		
2.09	2.43	1.53		
1.83	2.04	1.41		
1.71	1.67	1.31		
1.52	1.64	1.67	MB	
1.38	1.45	0.99	MB	PSD2

CONCWT=30.0% SGSL=1.075 Temp=16C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.03	4.67	0.67		
2.72	4.03	1.04		
2.42	3.45	1.35		
2.15	2.98	1.34		
1.92	2.62	1.51		
1.76	2.36	1.14	MD	
1.56	2.14	2.73	MD	
1.40	1.88	1.16	MB	
1.30	1.77	3.10	SB	PSD3

CONCWT=40.8% SGSL=1.105 Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
2.98	4.98	0.30		
2.68	4.36	0.56		
2.40	3.82	1.01		
2.14	3.38	1.41		
1.97	3.11	1.26		
1.81	2.80	1.23		
1.62	2.58	1.20	MD	
1.51	2.43	1.23	MD	
1.41	2.31	1.30	MB	
1.23	2.27	5.38	SB	PSD4

CONCWT=51.0% SGSL=1.135 Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.03	5.30	0.46		
2.76	4.78	0.95		
2.41	4.15	1.18		
2.10	3.60	1.41		
1.95	3.37	1.40		
1.80	3.07	1.44		
1.71	2.86	1.50		
1.59	2.67	1.59	MD	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MAY 1980

Solids Moisture= 7.8%
Specific Gravity of Dried Solids=1.307

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	420	841	2380	6350	50800
PSD1	24.5	37.3	49.4	58.1	70.9	83.8	100.0
PSD2	33.0	47.9	59.6	67.3	77.9	87.8	100.0
PSD3	41.3	56.4	68.1	75.3	84.8	93.3	100.0
PSD4	44.9	58.8	70.3	77.0	86.0	92.8	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=23C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.04	3.78	0.89		
2.71	3.05	0.92		
2.40	2.44	0.87		
2.13	1.95	1.36		
1.83	1.43	0.94		
1.55	1.06	0.73		
1.23	0.66	0.69		
0.92	0.41	0.52		

CONCWT=51.0%   SGSL=1.135   Temp=17C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.03	5.30	0.46		
2.76	4.78	0.95		
2.41	4.15	1.18		
2.10	3.60	1.41		
1.95	3.37	1.40		
1.80	3.07	1.44		
1.71	2.86	1.50		
1.59	2.67	1.53	MD	PSD1

CONCNT=51.0% SGSL=1.136 Temp= 7C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
2.99	5.57	1.69		PSD4
2.67	4.54	0.40		
2.39	3.68	0.83		
2.11	2.99	0.79		
1.96	2.58	0.84		
1.81	2.22	0.80		
1.65	1.92	0.84	MD	
1.51	1.70	0.85	MD	
1.39	1.50	0.85	MB	
1.28	1.32	0.77	MB	
1.14	1.06	0.76	SB	

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.4mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
SEPTEMBER 1980

Solids Moisture= 5.0%
Specific Gravity of Dried Solids=1.362

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	15.4	26.7	58.3	78.5	91.3	98.1	100.0
PSD2	21.9	34.0	62.6	78.8	89.5	97.2	100.0
PSD3	18.6	30.8	60.5	76.6	86.3	93.9	100.0
PSD4	21.3	31.7	59.6	76.7	88.2	97.9	100.0
PSD5	21.7	33.6	59.0	75.3	86.9	95.3	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.08	4.53	0.99		
2.76	3.66	1.82		
2.47	2.98	1.18		
2.14	2.28	1.19		
1.86	1.75	0.82		
1.57	1.30	0.96		
1.27	0.89	0.70		
0.94	0.49	0.47		

CONCWT=18.8%   SGSL=1.051   Temp=18C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.02	4.87	0.70		PSD1
2.73	4.10	1.16		
2.44	3.45	1.48		
2.12	2.81	1.53		
1.34	2.31	1.63		
1.56	1.95	1.56		
1.60	2.02	1.22		
1.91	2.45	1.12		
1.75	2.18	1.15	MD	
1.49	1.82	1.08	MD	
1.39	1.70	0.98	MD	PSD2

CONCWT=30.4%   SGSL=1.087   Temp=19C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
3.10	5.41	0.84		
2.72	4.47	1.35		
2.42	3.82	1.78		
2.08	3.12	1.58		
1.88	2.78	1.70	MD	
1.68	2.51	1.63	MD	
1.55	2.41	1.61	MD	PSD3

CONCWT=41.2%   SGSL=1.122   Temp=18C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
3.13	5.77	1.24		
2.79	4.90	1.07		
2.78	4.86	0.99		
2.48	4.17	0.54		
2.16	3.54	0.51		
2.01	3.24	0.71		
1.87	3.00	0.82		
1.69	2.70	0.96		
1.56	2.50	1.04	MD	
1.30	2.17	1.17	MB	
1.15	2.13	1.50	SB	PSD4

CONCWT=51.3%   SGSL=1.157   Temp=21C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
3.05	5.82	0.62		
2.69	4.95	0.39		
2.43	4.33	0.46		
2.30	4.10	0.61		
2.12	3.73	0.56		
1.86	3.27	0.92		
1.69	2.94	0.97		
1.57	2.70	1.09		PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980

Solids Moisture= 5.0%
Specific Gravity of Dried Solids=1.362

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	18.9	24.3	48.1	67.6	83.2	95.7	100.0
PSD2	29.5	37.4	60.5	76.3	88.4	97.9	100.0
PSD3	30.7	42.2	64.4	78.4	88.6	96.6	100.0
PSD4	39.5	47.7	69.2	80.2	88.4	95.9	100.0
PSD5	50.8	59.2	75.9	83.3	89.0	95.8	100.0

CONCWT= 0.0% SGSL=0.998 Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.08	4.53	0.99		
2.76	3.66	1.82		
2.47	2.98	1.18		
2.14	2.28	1.18		
1.86	1.75	0.82		
1.57	1.30	0.96		
1.27	0.89	0.70		
0.94	0.49	0.47		

CONCWT=53.1% SGSL=1.164 Temp=16C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
2.96	6.03	0.56		PSD1
2.50	4.92	1.28		
2.08	4.02	1.55		
1.72	3.27	1.90		

CONCWT=53.1%   SGSL=1.163   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	 RMS m/100m	FLOW REGIME	PSD NUMBER
3.07	6.83	0.41		
2.80	5.85	0.35		
2.46	4.76	0.30		
2.15	3.90	0.47		
1.86	3.16	0.81		
1.57	2.50	1.06	MD	
1.40	2.21	1.02	MD	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm RAW JUDY CREEK COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980

Solids Moisture=23.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	13.2	19.9	43.8	74.2	93.8	99.8	100.0
PSD2	18.7	26.9	54.9	81.1	94.6	98.1	100.0
PSD3	22.3	30.1	53.7	79.6	92.9	96.7	100.0
PSD4	14.3	19.8	37.5	61.8	86.7	98.7	100.0
PSD5	17.8	24.3	44.3	70.3	90.3	97.3	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=23C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.20	2.62	0.67		
2.94	2.26	0.39		
2.62	1.64	0.24		
2.39	1.56	0.18		
2.14	1.28	0.28		
1.82	0.95	0.31		
1.70	0.85	0.31		
1.55	0.71	0.29		
1.37	0.58	0.29		
0.75	0.19	0.23		

CONCWT=23.4%   SGSL=1.108   Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.17	4.76	0.25		PSD1
2.96	4.46	0.27		
2.69	4.13	0.27		
2.44	3.87	0.25		
2.21	3.65	0.25		
1.97	3.67	0.25	MD	
1.85	3.53	0.25	MD	
1.79	3.46	0.25	MB	
1.76	3.50	0.24	SB	PSD2

CONCNT=38.6% SGSL=1.181 Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.26	6.38	0.42		
3.03	5.96	0.32		
2.78	5.60	0.33		
2.54	5.26	0.30		
2.32	5.07	0.15		
2.42	5.15	0.68		
2.26	5.01	0.51		
2.18	5.05	0.55		
2.19	4.62	0.25		
2.20	5.16	0.49		
2.03	4.96	0.53	MD	
1.85	5.34	0.45	MB	
1.83	5.31	0.25	MB	
1.77	5.59	0.32	SB	PSD3

CONCNT=48.2% SGSL=1.253 Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.31	7.33	0.45		
3.10	7.03	0.43		
2.85	6.64	0.35		
2.68	6.19	0.38		
2.66	6.35	0.48		
2.44	6.26	0.53		
2.44	6.15	0.45		
2.33	6.18	0.76		
2.30	6.30	0.76		
2.29	5.84	0.41		
2.31	6.37	0.84		
2.15	5.79	0.77	MC	
2.18	5.61	0.73	MD	
1.98	6.40	0.89	MD	
1.96	5.94	0.92	MD	
2.03	5.69	1.05	MD	
1.82	6.86	0.81	MB	
1.82	6.63	0.71	MB	
1.68	6.72	0.30	MB	
1.62	6.28	0.41	SB	PSD4

CONCWT=58.6%   SGSL=1.326   Temp=21C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
3.24	8.17	0.59		
3.00	7.61	0.46		
2.72	7.09	0.42		
2.44	6.34	0.37		
2.44	6.85	0.39		
2.32	6.82	0.38		
2.34	6.75	0.40		
2.24	6.67	0.35		
2.09	6.64	0.41		
2.08	6.63	0.46		
1.93	6.71	0.61		
1.75	6.69	0.54	MD	
1.59	7.08	0.33	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
MARCH 1982

Solids Moisture= 6.6%
Specific Gravity of Dried Solids=1.500

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	12700	19000	25400	38100
PSD1	20.4	27.5	41.3	53.2	67.3	76.2	82.9	90.3	97.0
PSD2	18.7	24.7	37.6	47.6	55.8	67.9	85.9	92.7	98.1
PSD3	20.3	26.2	41.0	56.0	70.8	84.7	90.5	95.9	100.0

CONCWT= 0.0% SGSL=1.000 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.09	2.42		
2.72	1.92		
2.40	1.52		
2.05	1.15		
1.79	0.91		
1.55	0.71		
1.17	0.46		

CONCWT=33.3% SGSL=1.124 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.03	5.01		
2.81	4.74		
2.44	4.31		
2.16	3.77	MD	
1.87	3.72	MD	
1.78	3.45	MD	
1.72	3.57	MD	
1.65	3.47	MD	
1.50	3.22	SB	PSD1

CONCWT=44.7% SGSL=1.175 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.06	5.28		
2.90	5.12		
2.70	4.86		
2.50	4.48		
2.37	4.47		
2.12	4.18		
1.83	3.90	MD	
2.01	4.17	MD	
1.55	3.40	MD	
1.36	3.33	SB	PSD2

CONCWT=55.1% SGSL=1.224 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.18	5.68		
2.92	5.28		
2.77	5.00		
2.63	4.74		
2.43	4.54		
2.31	4.28	MD	
2.20	4.24	MD	
2.09	3.91	MD	
1.91	4.10	MD	
1.85	3.76	MD	
1.66	3.61	MD	
1.41	3.27	MD	
1.37	3.49	SB	PSD3

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN: MARCH 1982

Solids Moisture= 6.6%
Specific Gravity of Dried Solids=1.500

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	12700	19000	25400	38100
PSD1	16.3	21.6	34.0	46.6	62.6	77.9	86.1	90.8	96.8
PSD2	20.3	26.2	41.0	56.0	70.8	84.7	90.5	95.9	100.0

CONCWT= 0.0% SGSL=1.000 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.09	2.42		
2.72	1.92		
2.40	1.52		
2.05	1.15		
1.79	0.91		
1.55	0.71		
1.17	0.46		

CONCWT=55.1% SGSL=1.224 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.11	8.89		
2.85	7.78		
2.71	7.49		
2.66	6.99		
2.56	6.73		
2.42	6.42		
2.30	6.20		
2.08	5.86		
1.87	5.81		
1.80	5.62	MD	
1.65	5.75	MD	
1.55	5.41	MD	
1.34	5.29	SB	PSD1

CONCWT=55.1%   SGSL=1.224   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	FLOW REGIME	PSD NUMBER
3.18	5.68		
2.92	5.28		
2.77	5.00		
2.63	4.74		
2.43	4.54		
2.31	4.28	MD	
2.20	4.24	MD	
2.09	3.91	MD	
1.91	4.10	MD	
1.85	3.76	MD	
1.66	3.61	MD	
1.41	3.27	MD	
1.37	3.49	SB	PSD2

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm FORDING COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980

Solids Moisture= 7.8%
Specific Gravity of Dried Solids=1.307

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	14.8	27.7	52.4	68.5	81.5	95.8	100.0
PSD2	18.0	31.2	55.2	68.4	80.4	96.4	100.0
PSD3	16.8	27.7	61.8	74.7	88.4	97.9	100.0
PSD4	21.2	33.0	54.8	67.0	80.1	95.0	100.0
PSD5	21.6	34.0	55.6	68.5	83.2	97.5	100.0

CONCWT= 0.0% SGSL=0.998 Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
3.14	2.56	0.36		
3.07	2.46	0.36		
2.71	1.94	0.28		
2.37	1.51	0.29		
2.09	1.19	0.24		
1.82	0.92	0.30		
1.66	0.77	0.29		
1.51	0.66	0.30		
1.35	0.53	0.31		
1.10	0.37	0.28		
0.77	0.19	0.27		

CONCWT=18.7% SGSL=1.045 Temp=18C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
2.96	2.91	0.44		PSD1
2.71	2.63	0.41		
2.40	2.23	0.32		
2.08	1.95	0.17		
1.85	1.73	0.18		
1.67	1.60	0.36		
1.55	1.52	0.33	SB	PSD2

CONCWT=30.2%   SGSL=1.075   Temp=21C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
2.97	3.31	0.40		
2.73	2.99	0.23		
2.38	2.59	0.03		
2.05	2.12	0.41	MD	
1.94	2.05	0.48	SB	PSD3

CONCWT=41.1%   SGSL=1.106   Temp=20C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
2.95	3.62	0.38		
2.68	3.27	0.16		
2.52	3.11	0.08		
2.29	2.76	0.16	MD	
2.17	2.55	0.11	MD	
1.97	2.32	0.09	MD	
1.85	2.34	0.03	MD	
1.80	2.31	0.19	SB	PSD4

CONCWT=51.5%   SGSL=1.137   Temp=20C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
3.22	4.44	0.25		
3.04	4.17	0.27		
2.75	3.75	0.18		
2.45	3.45	0.18		
2.18	2.99	0.13		
1.99	2.67	0.08	MD	
1.83	2.50	0.14	MD	
1.68	2.70	0.24	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm KAISER COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

Solids Moisture= 5.0%
Specific Gravity of Dried Solids=1.362

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	44	210	841	2380	6350	13000	50800
PSD1	13.5	32.9	68.0	86.5	97.9	99.4	100.0
PSD2	18.6	33.1	63.8	80.9	91.4	98.1	100.0
PSD3	19.6	32.2	62.4	80.5	91.1	97.5	100.0
PSD4	19.7	31.3	60.4	79.3	91.1	97.5	100.0
PSD5	20.2	29.4	58.3	77.9	90.0	97.2	100.0

CONCWT= 0.0%   SGSL=0.999   Temp=18C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.25	2.71	0.32		
3.05	2.42	0.29		
2.69	1.91	0.19		
2.44	1.60	0.15		
2.14	1.25	0.11		
1.84	0.93	0.14		
1.55	0.67	0.19		
1.23	0.45	0.18		
0.92	0.25	0.17		

CONCWT=18.8%   SGSL=1.051   Temp=19C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.21	3.04	0.33		PSD1
3.02	2.76	0.30		
2.81	2.45	0.24		
2.57	2.19	0.22		
2.34	1.94	0.17		
2.21	1.82	0.14		
2.07	1.65	0.15		
1.89	1.59	0.19	MD	
1.96	1.53	0.17	MD	
1.85	1.49	0.19	MD	
1.77	1.54	0.22	SB	PSD2

CONCWT=30.4% SGSL=1.087 Temp=18C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.35	3.58	0.32		
3.11	3.23	0.42		
2.87	2.90	0.34		
2.66	2.62	0.22		
2.41	2.37	0.18		
2.25	2.22	0.17		
2.06	2.05	0.13		
1.92	1.97	0.16	MD	
1.90	1.90	0.20	MD	
1.82	1.89	0.20	MD	
1.75	1.97	0.18	MB	
1.68	1.80	0.23	SB	PSD3

CONCWT=41.2% SGSL=1.122 Temp=19C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.37	3.72	0.35		
3.35	3.68	0.44		
3.11	3.35	0.41		
2.86	3.04	0.36		
2.74	2.88	0.30		
2.52	2.60	0.22		
2.26	2.32	0.20		
2.07	2.17	0.13		
1.94	2.06	0.12		
1.80	2.03	0.15	MD	
1.76	2.12	0.17	MB	
1.69	2.10	0.20	MB	
1.62	2.15	0.20	SB	PSD4

CONCWT=51.3% SGSL=1.157 Temp=20C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
3.36	3.98	0.50		
3.12	3.63	0.42		
2.81	3.25	0.34		
2.55	2.93	0.24		
2.28	2.63	0.19		
2.21	2.53	0.17		
2.04	2.34	0.16	MD	
1.88	2.17	0.13	MB	
1.78	2.12	0.12	MB	
1.66	2.08	0.17	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm RAW JUDY CREEK COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

Solids Moisture=23.6%
Specific Gravity of Dried Solids=1.727

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	31.8	41.8	64.3	86.1	95.8	99.5	100.0
PSD2	19.9	28.6	55.7	84.1	96.4	99.9	100.0
PSD3	19.1	27.3	54.0	83.4	96.5	99.8	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=20C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
4.18	1.92	0.52		
3.89	1.69	0.47		
3.51	1.41	0.43		
3.23	1.21	0.46		
2.87	1.00	0.50		
2.55	0.77	0.57		
2.22	0.61	0.30		
1.77	0.40	0.17		

CONCWT=23.4%   SGSL=1.108   Temp=19C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN	RMS	REGIME	NUMBER
	m/100m	m/100m		
4.12	3.50	0.62		PSD1
3.94	3.30	0.62		
3.74	3.01	0.60		
3.59	2.85	0.54		
3.47	2.72	0.55		
3.27	2.75	0.55	MD	
3.14	2.68	0.49	MD	
2.99	3.01	0.55	MD	
3.00	2.88	0.52	MD	
2.97	3.15	0.57	S3	PSD2

CONCWT=36.6%   SGSL=1.181   Temp=20C

VELOCITY m/sec	HEADLOSS		FLOW REGIME	PSD NUMBER
	MEAN m/100m	RMS m/100m		
4.01	4.49	0.92		
4.02	4.65	0.84		
3.90	4.65	0.84		
3.92	4.80	0.88		
4.00	4.86	0.90		
3.87	4.67	0.84		
3.83	4.69	0.79		
3.71	4.25	0.67		
3.61	3.98	0.59		
3.44	3.76	0.57		
3.29	3.53	0.71		
3.17	3.47	0.69	MD	
3.04	3.53	0.75	MD	
2.85	3.43	0.99	MD	
2.69	4.05	0.64	SB	PSD3

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm FORDING COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
JULY 1980

Solids Moisture= 7.8%
Specific Gravity of Dried Solids=1.307

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	12.7	24.6	50.4	66.7	82.8	98.6	100.0
PSD2	17.5	32.6	58.5	73.6	87.7	98.1	100.0
PSD3	22.1	38.8	66.3	72.1	85.5	96.0	100.0
PSD4	13.7	27.0	54.6	70.6	84.6	96.3	100.0

CONCWT= 0.0%   SGSL=0.998   Temp=21C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN m/100m	RMS m/100m	REGIME	NUMBER
4.11	1.94	0.70		
3.68	1.63	0.51		
3.24	1.32	0.49		
2.79	1.02	0.61		
2.33	0.77	0.32		
1.95	0.58	0.21		

CONCWT=18.7%   SGSL=1.045   Temp=19C

VELOCITY	HEADLOSS		FLOW	PSD
m/sec	MEAN m/100m	RMS m/100m	REGIME	NUMBER
4.23	2.48	0.58		PSD1
3.72	2.10	0.43		
3.39	1.82	0.51		
3.17	1.73	0.53		
2.90	1.56	0.54		
2.63	1.34	0.87	MD	
2.37	1.17	0.59	MD	
2.24	1.31	0.34	SB	PSD2

CONCWT=29.8%   SGSL=1.074   Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.15	2.63	0.95		
4.02	2.47	0.52		
3.68	2.23	0.45		
3.29	2.01	0.53		
3.10	1.83	0.54		
2.88	1.57	0.55		
2.53	1.56	0.67	MD	
2.38	1.85	0.66	SB	PSD3

CONCWT=38.0%   SGSL=1.096   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.18	2.70	0.58		
3.73	2.38	0.53		
3.22	2.04	0.57		
3.16	2.14	0.66		
3.05	1.95	0.57		
2.99	1.87	0.52	MD	
2.85	1.90	0.56	MD	
2.73	1.78	0.58	MB	
2.60	1.43	0.65	MB	
2.40	1.53	1.11	SB	PSD4

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

Solids Moisture= 5.0%
Specific Gravity of Dried Solids=1.362

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	19.9	33.5	64.3	81.8	93.2	99.2	100.0
PSD2	20.3	33.9	65.4	34.1	94.2	98.1	100.0
PSD3	19.1	31.4	63.1	82.0	93.8	98.3	100.0
PSD4	20.4	32.8	63.5	81.6	93.3	98.5	100.0
PSD5	18.3	29.4	61.8	81.2	93.3	98.1	100.0

CONCWT= 0.0% SGSL=0.998 Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.18	1.92	0.52		
3.89	1.69	0.47		
3.51	1.41	0.43		
3.23	1.21	0.46		
2.87	1.00	0.50		
2.55	0.77	0.57		
2.22	0.61	0.30		
1.77	0.40	0.17		

CONCWT=18.8% SGSL=1.051 Temp=21C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.19	2.21	0.53		PSD1
3.99	2.05	0.47		
3.82	1.90	0.41		
3.69	1.82	0.45		
3.47	1.65	0.51		
3.31	1.54	0.45		
3.22	1.47	0.47		
3.03	1.37	0.49		
2.86	1.30	0.57	MD	
2.40	1.70	0.14	SB	PSD2

CONCWT=30.4%   SGSL=1.086   Temp=22C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.09	2.23	0.51		
4.01	2.15	0.49		
3.86	2.03	0.45		
3.72	1.92	0.44		
3.49	1.78	0.52		
3.31	1.72	0.52		
3.15	1.66	0.45		
2.94	1.49	0.52	MD	
2.75	1.38	0.62	MD	
2.61	1.36	0.88	MD	
2.52	1.37	1.08	MD	
2.39	1.38	2.60	SB	PSD3

CONCWT=43.0%   SGSL=1.128   Temp=16C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER.
4.25	2.52	1.13		
3.76	2.15	0.49		
3.29	1.88	0.60		
3.18	1.75	0.49		
2.97	1.60	0.46		
2.73	1.50	0.54	MD	
2.64	1.49	0.56	SB	PSD4

CONCWT=53.6%   SGSL=1.166   Temp=12C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.18	2.66	0.66		
3.71	2.34	0.51		
3.21	2.00	0.59		
2.75	1.79	0.58	MD	
2.70	1.66	0.64	MD	
2.61	1.60	0.76	SB	PSD5

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980

Solids Moisture= 5.0%
Specific Gravity of Dried Solids=1.362

PARTICLE SIZE DISTRIBUTIONS
Weight Percent Passing Each Sieve

SIZE micr.	74	210	841	2380	6350	19000	50800
PSD1	21.8	33.6	62.2	78.9	90.7	97.6	100.0
PSD2	23.0	34.6	62.8	79.4	91.1	97.6	100.0
PSD3	27.1	37.6	67.9	83.7	93.8	98.2	100.0
PSD4	30.8	41.7	70.6	84.9	93.7	98.6	100.0
PSD5	36.7	45.5	75.0	87.1	94.2	98.7	100.0

CONCWT= 0.0% SGSL=0.999 Temp=14C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.19	1.98	0.63		
3.66	1.54	0.51		
3.22	1.22	0.50		
2.74	0.92	0.66		
2.28	0.66	0.32		
1.82	0.45	0.22		
1.66	0.42	0.18		

CONCWT=53.6% SGSL=1.166 Temp=12C

VELOCITY m/sec	HEADLOSS MEAN m/100m	HEADLOSS RMS m/100m	FLOW REGIME	PSD NUMBER
4.18	2.66	0.66		
3.71	2.34	0.51		
3.21	2.00	0.59		
2.75	1.70	0.58	MD	
2.70	1.66	0.64	MD	
2.61	1.60	0.76	SB	PSD1

CONCWT=53.6% SGSL=1.165 Temp=19C

VELOCITY m/sec	HEADLOSS MEAN m/100m	RMS m/100m	FLOW REGIME	PSD NUMBER
4.17	2.44	0.57		PSD5
3.74	2.09	0.46		
3.16	1.67	0.58		
2.76	1.42	0.70		
2.41	1.24	0.50		
2.34	1.21	0.43		
2.01	1.09	0.35	SB	

APPENDIX B

EMPIRICAL CORRELATIONS - RESULTS IN TABULAR FORM

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-14 mesh RAW JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
APRIL 1980

CONCWT=23.2%   SGSL=1.107   CONCV=22.0%   Cd= 7.595   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	17.59	101.01	0.84
2.68	15.21	77.99	1.33
2.38	11.76	61.51	1.07
2.10	9.66	47.89	1.23
1.83	7.67	36.36	1.32
1.52	6.15	25.09	2.01
1.03	6.14	11.52	8.55
1.04	6.75	11.74	9.61

CONCWT=30.4%   SGSL=1.146   CONCV=29.8%   Cd= 7.792   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.01	18.45	99.63	0.89
2.71	15.46	80.76	0.94
2.44	12.79	65.47	0.93
2.13	10.06	49.89	0.95
1.80	8.11	35.63	1.35
1.59	6.97	27.80	1.68
1.34	5.86	19.75	2.39
1.26	5.86	17.46	3.05

CONCWT=37.3% SGSL=1.185 CONCV=37.8% Cd= 8.059 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.02	19.83	102.03	0.97
2.71	16.14	82.16	0.93
2.41	12.62	64.98	0.81
2.10	10.31	49.34	0.96
1.83	8.49	37.46	1.16
1.62	7.96	29.36	1.79
1.40	9.10	21.93	3.92
1.40	9.10	21.93	3.92

CONCWT=42.5% SGSL=1.217 CONCV=44.2% Cd= 8.570 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.02	19.93	105.20	0.83
3.02	20.00	105.20	0.84
2.74	17.10	86.59	0.90
2.44	14.30	68.67	0.99
2.16	11.69	53.81	1.04
1.89	10.27	41.20	1.43
1.80	9.20	37.37	1.34
1.62	10.98	30.27	2.94

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-14 mesh WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980

CONCWT=22.7%   SGSL=1.096   CONCV=21.4%   Cd= 5.583   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.08	17.31	95.45	0.68
2.68	13.72	72.27	0.77
2.41	11.37	58.44	0.79
2.10	9.17	44.37	0.96
1.77	7.71	31.52	1.76
1.43	7.32	20.57	4.27
1.34	7.49	18.07	5.61
1.19	6.61	14.25	6.53
1.16	7.75	13.54	9.08
1.04	9.52	10.38	15.84

CONCWT=28.9%   SGSL=1.126   CONCV=28.0%   Cd= 5.884   Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	17.38	96.09	0.61
2.71	14.25	75.96	0.66
2.41	11.62	59.99	0.70
2.13	9.77	46.86	0.90
1.77	8.57	32.36	1.90
1.65	8.26	28.12	2.42
1.52	8.14	23.86	3.25
1.37	8.42	19.39	4.92
1.19	8.74	14.63	7.75
1.01	9.20	10.54	12.38
1.04	10.56	11.17	13.83

CONCWT=35.2% SGSL=1.159 CONCV=35.0% Cd= 5.779 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.02	16.91	93.36	0.45
2.77	14.57	78.54	0.47
2.47	12.26	62.45	0.59
2.13	10.48	46.44	0.98
1.99	8.78	36.56	1.13
1.68	8.89	28.89	2.12
1.46	8.60	21.82	3.33
1.40	8.54	20.06	3.76
1.19	8.74	14.50	6.19
1.04	8.74	11.07	8.63
0.91	10.27	8.48	14.25

CONCWT=45.1% SGSL=1.213 CONCV=47.0% Cd= 7.584 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	21.70	109.07	0.96
2.77	19.60	89.96	1.19
2.38	16.70	66.41	1.59
2.13	15.30	53.19	2.02
1.77	13.20	36.73	2.36
1.68	12.50	33.09	3.06
1.55	13.10	28.17	4.15
1.37	10.20	22.01	3.96
1.19	9.60	16.60	5.23
1.10	9.50	14.19	6.25
0.94	8.30	10.36	7.55
0.79	9.00	7.32	12.14
0.61	8.20	4.36	18.37

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-8 MESH WASHED JUDY CREEK COAL IN WATER
52.6mm I.D. OPEN LOOP PIPELINE
MARCH 1980

CONCWT=22.2% SGSL=1.094 CONCV=20.9% Cd= 3.854 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.08	17.95	79.31	0.90
2.74	14.93	62.76	1.05
2.38	12.01	47.35	1.26
2.10	10.41	36.87	1.77
1.95	9.45	31.79	2.01
1.80	8.99	27.09	2.68
1.68	8.19	23.59	3.19
1.52	8.26	19.31	4.49
1.37	8.07	15.69	6.12
1.19	7.68	11.84	8.55
1.04	7.46	9.04	11.69
0.85	3.10	6.04	20.77

CONCWT=30.1% SGSL=1.132 CONCV=29.3% Cd= 5.214 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.02	18.94	88.68	1.02
2.71	15.60	71.41	1.02
2.44	12.60	57.89	0.91
2.13	10.48	44.11	1.18
1.80	9.09	31.50	1.96
1.52	7.96	22.46	2.96
1.19	7.99	13.77	6.43
0.88	8.10	7.52	13.71
0.76	9.17	5.62	21.72

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CONCWT=35.3%  SGSL=1.159  CONCV=35.1%  Cd= 3.792  Temp=17C

 VELOCITY m/sec    HEADLOSS m/100m     1/KSI          PHI
      3.09              18.52          73.17          0.62
      2.78              16.24          64.08          0.83
      2.46              14.39          50.18          1.21
      2.14              11.59          37.97          1.35
      1.81              10.59          27.17          2.33
      1.69              10.38          23.68          2.88
      1.50               9.88          18.66          3.90
      1.50              10.06          18.66          4.03
      1.38               9.67          15.79          4.81
      1.22               9.52          12.34          6.55
      1.10               9.60          10.03          8.54
      0.90               9.88           6.72         13.89
      0.75              10.34           4.66         21.33
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SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-8 mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980

CONCWT=22.5% SGSL=1.096 CONCV=23.7% Cd= 6.268 Temp= 3C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	7.53	54.15	0.57
2.74	6.59	43.70	0.85
2.44	5.82	34.66	1.33
2.13	5.16	26.41	2.06
1.83	4.60	19.49	3.14
1.65	4.07	15.85	3.62
1.52	3.93	13.45	4.54
1.40	4.20	11.41	6.65
1.28	4.12	9.54	8.30
1.10	3.96	7.04	11.55
1.16	3.99	7.83	10.23

CONCWT=35.4% SGSL=1.161 CONCV=39.4% Cd= 6.689 Temp= 8C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	8.03	55.94	0.53
2.74	7.31	45.14	0.86
2.44	6.99	35.80	1.46
2.13	6.49	27.28	2.21
1.80	5.59	19.48	2.99
1.65	5.44	16.37	3.75
1.52	5.26	13.89	4.52
1.40	5.50	11.79	6.01
1.22	6.09	8.35	9.57

CONCWT=47.0% SGSL=1.225 CONCV=55.3% Cd= 6.235 Temp= 6C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	8.54	54.00	0.49
2.74	8.00	43.58	0.81
2.44	7.44	34.56	1.19
2.13	7.19	26.33	1.89
1.89	6.96	20.73	2.64
1.68	6.80	16.38	3.56
1.52	6.96	13.41	4.77
1.40	7.44	11.33	6.34
1.22	7.77	8.64	9.07
1.10	8.53	7.02	12.64

CONCWT=57.4% SGSL=1.290 CONCV=71.1% Cd= 6.516 Temp= 5C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	10.13	55.20	0.70
2.74	9.09	44.55	0.89
2.44	8.02	35.33	1.38
2.13	8.00	26.92	1.78
1.83	7.36	19.87	2.45
1.68	7.17	16.75	2.97
1.52	6.97	13.71	3.69
1.37	6.80	11.14	4.58
1.22	6.76	8.83	5.91
1.10	6.70	7.18	7.32
1.04	6.76	6.42	8.32

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-9.5mm RAW JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980

CONCWT=23.1% SGSL=1.107 CONCV=21.9% Cd= 4.603 Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.20	9.33	42.29	1.49
3.06	8.85	38.67	1.67
2.74	7.79	31.00	2.13
2.44	6.80	24.59	2.65
2.13	6.01	18.74	3.58
1.84	5.37	13.98	4.92
1.65	4.99	11.24	6.14
1.49	4.79	9.17	7.90
1.34	4.73	7.42	10.21
1.22	4.99	6.15	13.86

CONCWT=37.1% SGSL=1.184 CONCV=37.6% Cd= 4.949 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.26	10.71	45.51	1.27
3.06	10.15	40.10	1.52
2.74	9.09	32.15	1.91
2.38	8.03	24.26	2.55
2.07	7.13	18.35	3.30
1.93	6.44	14.34	4.07
1.65	6.08	11.66	4.98
1.51	5.98	9.76	6.15
1.37	5.90	8.04	7.71
1.19	5.90	6.06	10.70

CONCWT=47.7%   SGSL=1.251   CONCV=51.0%   Cd= 5.077   Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.23	11.69	45.26	1.26
3.05	11.29	40.35	1.49
2.74	10.44	32.57	1.91
2.44	9.49	25.83	2.38
2.13	8.66	19.68	3.10
1.92	8.13	15.99	3.77
1.62	7.68	11.38	5.39
1.34	6.96	7.79	7.42
1.25	6.83	6.78	8.46

CONCWT=57.9%   SGSL=1.322   CONCV=65.4%   Cd= 5.246   Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.93	11.81	37.85	1.48
2.74	11.25	33.10	1.71
2.41	10.28	25.61	2.20
2.16	9.51	20.57	2.68
1.80	8.78	14.29	3.06
1.65	8.54	12.00	4.60
1.49	8.21	3.79	5.55
1.28	8.00	7.22	7.54
1.22	7.93	6.56	8.27

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-9.5mm WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
JANUARY 1980

CONCWT=21.5% SGSL=1.091 CONCV=22.7% Cd= 4.330 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.34	8.72	54.47	0.77
3.02	7.49	44.54	0.94
2.74	6.68	36.66	1.28
2.42	5.77	28.60	1.74
2.27	5.40	25.16	2.06
2.16	5.11	22.79	2.28
1.98	4.77	19.14	2.30
1.84	4.46	16.53	3.38
1.71	4.18	14.28	3.03
1.55	3.95	11.73	4.99
1.34	3.78	8.77	7.29

CONCWT=34.0% SGSL=1.152 CONCV=37.9% Cd= 3.944 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.26	9.65	49.54	0.96
3.05	8.88	43.36	1.10
2.76	7.92	35.51	1.36
2.44	7.09	27.75	1.84
2.10	6.20	20.53	2.50
1.86	5.61	16.13	3.14
1.69	5.18	13.31	3.71
1.54	4.95	11.06	4.53
1.40	4.83	9.14	5.67
1.28	4.58	7.64	6.51
1.19	4.99	6.60	8.85

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CONCWT=45.2%  SGSL=1.214  CONCV=53.1%  Cd= 3.685  Temp=19C

 VELOCITY m/sec     HEADLOSS m/100m     1/KSI          PHI
      3.03                9.97          41.36          1.15
      2.74                9.31          33.83          1.52
      2.47                8.77          27.49          1.98
      2.13                8.00          20.44          2.73
      1.83                7.12          15.09          3.51
      1.58                6.75          11.25          4.78
      1.37                6.56           8.46          6.49
      1.22                6.41           6.71          8.20
      1.10                7.93           5.45         13.14
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CONCWT=55.3%  SGSL=1.276  CONCV=68.3%  Cd= 4.025  Temp=13C

 VELOCITY m/sec     HEADLOSS m/100m     1/KSI          PHI
      3.11               10.82          45.49          0.91
      2.71               10.15          34.54          1.39
      2.38                9.60          26.64          1.95
      2.04                9.01          19.57          2.77
      1.77                8.77          14.73          3.86
      1.52                8.30          10.87          5.16
      1.34                7.92           8.44          6.46
      1.10                8.26           5.69         10.31
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SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-9.5mm +8mesh WASHED JUDY CREEK COAL IN WATER
107.6mm I.D. CLOSED LOOP PIPELINE
APRIL 1980

CONCWT=22.5% SGSL=1.096 CONCV=21.2% Cd= 2.848 Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.11	10.93	33.96	3.00
2.87	9.99	28.92	3.44
2.76	9.65	26.74	3.74
2.44	8.38	20.00	4.46
2.19	7.64	16.84	5.45
1.95	6.99	13.35	6.75
1.68	6.36	9.91	8.95
1.49	6.04	7.79	11.37
1.40	5.88	6.88	12.82
1.22	5.45	5.23	16.06
1.43	5.27	7.18	10.41
1.34	5.13	6.30	11.82
0.91	4.87	2.91	26.71
0.85	4.87	2.54	30.78

CONCWT=35.4% SGSL=1.160 CONCV=35.3% Cd= 3.157 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	12.74	34.39	2.79
2.74	12.13	27.75	3.67
2.50	11.46	23.10	4.42
2.16	10.43	17.25	5.81
1.83	9.27	12.38	7.47
1.65	8.88	10.06	9.06
1.46	8.48	7.88	11.33
1.31	8.38	6.34	14.16
1.22	8.21	5.59	16.08
1.10	8.06	4.47	19.51
0.91	7.95	3.06	28.14

B15

CONCWT=47.0% SGSL=1.225 CONCV=49.4% Cd= 3.206 Temp=11C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.11	15.10	36.02	2.50
2.71	13.82	27.35	3.29
2.41	12.86	21.63	4.08
2.13	12.12	16.90	5.17
1.83	11.49	12.47	6.34
1.52	10.77	8.60	9.70
1.40	10.61	7.30	11.36
1.22	10.20	5.54	14.45
1.07	10.07	4.26	18.56
0.91	10.20	3.08	25.81
0.85	9.97	2.69	28.72
0.79	10.00	2.32	33.11

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-3.5mm RAW JUDY CREEK COAL IN WATER
156.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980

CONCWT=23.4% SGSL=1.106 CONCV=22.6% Cd= 4.722 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.04	6.35	26.71	2.66
2.79	5.70	22.50	3.00
2.43	4.96	17.07	3.83
2.16	4.56	13.49	5.03
1.97	4.28	11.22	6.07
1.83	4.17	9.68	7.26
1.69	4.00	8.26	8.51
1.54	3.90	6.86	10.49
1.40	4.23	5 67	15.06
1.43	4.36	5.91	14.68
1.28	4.00	4.74	16.95

CONCWT=36.6% SGSL=1.181 CONCV=37.6% Cd= 5.102 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.06	8.10	28.14	2.72
2.76	7.42	22.89	3.29
2.49	6.80	18.63	3.92
2.12	6.49	13.51	5.74
1.97	6.27	11.66	6.62
1.82	6.10	9.95	7.75
1.68	6.14	8.43	9.46
1.54	6.34	7.13	11.99
1.38	7.03	5.72	17.13
1.31	5.97	5.16	15.80

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CONCWT=48.2%  SGSL=1.253  CONCV=52.5%  Cd= 4.448  Temp=20C

 VELOCITY m/sec    HEADLOSS m/100m    1/KSI       PHI
      3.10              9.68          26.98       2.63
      2.82              8.38          22.32       3.04
      2.41              7.80          16.31       3.88
      2.24              7.65          14.09       4.57
      2.00              7.42          11.23       5.82
      1.76              8.10           8.70       8.71
      1.67              8.50           7.83      10.36
      1.48              8.31           6.15      13.00
      1.37              8.04           5.27      14.67
      1.32              9.06           4.89      18.07
      1.24             10.12           4.32      23.07


CONCWT=58.6%  SGSL=1.326  CONCV=67.6%  Cd= 4.257  Temp=21C

 VELOCITY m/sec    HEADLOSS m/100m    1/KSI       PHI
      3.03             12.86          25.22       3.43
      2.72             11.81          20.32       4.01
      2.39             10.40          13.69       4.63
      2.09              9.66          12.00       5.76
      1.97              9.36          10.66       6.33
      1.74              9.40           8.32       8.35
      1.65              9.22           7.48       9.13
      1.42              8.71           5.54      11.67
      1.19              9.84           3.89      10.96
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SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-9.5mm WASHED JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MARCH 1980

CONCWT=22.5% SGSL=1.096 CONCV=24.3% Cd= 5.940 Temp=10C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.35	6.04	44.35	0.95
3.05	5.46	36.76	1.31
2.74	4.82	29.67	1.71
2.44	4.29	23.53	2.28
2.29	3.95	20.73	2.48
2.13	3.76	17.93	3.05
1.98	3.51	15.49	3.51
1.83	3.39	13.24	4.37
1.65	3.20	10.76	5.56
1.52	3.23	9.13	7.21
1.40	3.26	7.75	9.15

CONCWT=35.3% SGSL=1.160 CONCV=40.4% Cd= 5.028 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.34	7.52	40.57	1.38
3.05	7.03	33.83	1.81
2.73	6.22	27.11	2.12
2.41	5.58	21.12	2.69
2.06	5.17	15.43	3.89
1.83	4.98	12.18	5.12
1.52	5.47	8.40	9.19
1.69	5.31	10.27	6.39
1.52	5.40	8.40	3.06

CONCWT=47.0% SGSL=1.225 CONCV=56.8% Cd= 4.879 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.41	9.53	41.66	1.59
3.05	8.82	33.33	2.03
2.83	8.36	28.69	2.36
2.44	8.35	21.33	3.62
2.23	8.03	17.82	4.38
2.13	7.79	16.25	4.64
1.98	7.36	14.05	5.17
1.83	7.08	12.00	5.92
1.68	7.07	10.11	7.19
1.52	7.02	8.23	8.89
1.34	7.13	6.43	11.82
1.19	7.68	5.07	16.35

CONCWT=57.4% SGSL=1.289 CONCV=73.0% Cd= 4.394 Temp=13C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.29	9.64	36.81	1.45
3.05	9.28	31.63	1.75
2.74	8.91	25.53	2.27
2.44	8.74	20.25	3.04
2.13	8.63	15.43	4.19
1.83	8.58	11.39	5.91
1.65	8.58	9.26	7.41
1.52	8.54	7.86	8.76
1.37	8.09	6.38	10.21
1.19	8.91	4.82	15.08
1.07	8.25	3.89	17.06

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-9.5mm +8 mesh RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
MAY 1980

CONCWT=23.4% SGSL=1.108 CONCV=21.2% Cd= 3.733 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.22	8.64	25.08	4.52
3.05	8.22	22.50	4.98
2.72	7.54	17.89	6.23
2.47	6.97	14.76	7.35
2.17	6.41	11.39	9.32
1.99	6.11	9.58	10.93
1.83	5.94	8.10	13.00
1.73	5.78	7.24	14.36
1.54	5.52	5.74	17.75
1.40	4.66	4.74	17.83
1.26	5.32	3.84	26.42

CONCWT=36.5% SGSL=1.181 CONCV=35.4% Cd= 4.356 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.21	12.62	25.93	5.42
3.07	12.10	24.63	5.75
2.74	10.93	19.62	6.70
2.45	10.29	15.69	8.17
2.17	10.05	12.31	10.56
2.02	9.72	10.67	11.91
1.85	9.45	8.95	13.99
1.70	9.09	7.55	15.01
1.57	9.26	6.44	19.34
1.43	8.42	5.34	21.05
1.30	8.16	4.42	24.64
1.07	7.61	2.99	33.57

CONCWT=48.2% SGSL=1.254 CONCV=49.5% Cd= 3.887 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.24	18.07	25.90	5.23
3.09	15.43	23.56	5.57
2.75	14.20	18.66	6.61
2.43	13.28	14.57	8.08
2.18	12.82	11.73	9.86
2.04	12.49	10.27	11.03
1.84	11.49	8.35	12.46
1.71	11.84	7.22	15.01
1.55	10.40	5.93	15.85
1.48	10.84	5.40	18.22
1.32	10.13	4.30	21.23
1.19	8.73	3.49	22.14
1.19	8.79	3.49	22.31
1.00	9.19	2.47	32.76

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980

CONCWT=23.4% SGSL=1.107 CONCV=23.0% Cd= 5.118 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.01	6.14	27.88	2.62
2.76	5.59	23.44	3.08
2.37	4.80	17.23	4.07
2.13	4.37	13.96	4.96
1.85	3.91	10.53	6.38
1.68	3.77	8.69	7.99
1.56	3.53	7.49	8.85
1.43	3.34	6.29	10.29
1.42	3.26	6.20	10.12
1.05	2.74	3.39	16.62

CONCWT=36.6% SGSL=1.180 CONCV=38.4% Cd= 3.562 Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.03	8.00	23.57	2.80
2.70	7.37	18.72	3.53
2.45	6.83	15.41	4.18
2.17	6.26	12.09	5.15
1.89	5.67	9.17	6.42
1.73	5.51	7.68	7.68

CONCWT=48.2% SGSL=1.253 CONCV=53.7% Cd= 3.117 Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.04	9.97	22.19	2.92
2.73	9.08	17.90	3.44
2.45	8.36	14.42	4.08
2.14	7.66	11.06	5.10
1.98	7.36	9.42	5.84
1.87	7.12	8.40	6.40
1.68	6.88	6.78	7.84
1.63	7.07	6.38	8.66
1.55	6.83	5.77	9.28
1.38	6.66	4.57	11.53

CONCWT=58.6% SGSL=1.326 CONCV=69.0% Cd= 4.017 Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.09	12.33	26.03	3.02
2.76	11.14	20.77	3.50
2.47	10.23	16.63	4.12
2.55	10.25	17.73	3.62
2.06	9.02	11.57	5.38
1.83	8.57	9.13	6.59
1.66	7.84	7.51	7.33
1.58	7.72	6.81	8.00
1.42	7.52	5.50	9.71
1.21	7.24	3.99	12.91

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm RAW JUDY CREEK COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, JUNE 1980

CONCWT=58.6%   SGSL=1.326   CONCV=69.0%   Cd= 4.017   Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.09	12.33	26.03	3.02
2.76	11.14	20.77	3.50
2.47	10.23	16.63	4.12
2.55	10.25	17.73	3.82
2.06	9.02	11.57	5.38
1.83	8.57	9.13	6.59
1.66	7.84	7.51	7.33
1.58	7.72	6.81	8.00
1.42	7.49	5.50	9.68
1.21	7.24	3.99	12.31

CONCWT=58.6%   SGSL=1.326   CONCV=69.0%   Cd= 6.172   Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.95	9.89	29.40	2.41
2.73	9.02	25.17	2.61
2.36	7.58	18.81	2.99
2.05	6.45	14.20	3.43
1.77	5.60	10.58	4.08
1.70	5.41	9.76	4.30
1.50	4.31	7.60	4.36
1.37	4.46	6.34	5.54
1.17	3.77	4.62	6.42
1.01	3.42	3.45	7.84

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
JUNE 1980

CONCWT=18.6% SGSL=1.044 CONCV=16.5% Cd= 4.513 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.01	4.19	44.84	0.57
2.72	3.54	36.61	0.67
2.38	2.92	28.03	1.01
2.09	2.48	21.62	1.55
1.83	2.04	16.57	1.91
1.71	1.87	14.47	2.18
1.52	1.64	11.43	2.92
1.38	1.45	9.42	3.37

CONCWT=30.0% SGSL=1.075 CONCV=27.4% Cd= 6.095 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.03	4.67	52.78	0.65
2.72	4.03	42.53	0.86
2.42	3.45	33.66	1.12
2.15	2.98	26.57	1.46
1.92	2.62	21.19	1.87
1.76	2.36	17.81	2.16
1.56	2.14	13.39	2.91
1.40	1.88	11.27	3.34
1.30	1.77	9.71	3.91

CONCWT=40.8% SGSL=1.105 CONCV=38.3% Cd= 6.726 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.98	4.98	53.63	0.78
2.68	4.36	43.38	1.00
2.40	3.82	34.79	1.25
2.14	3.38	27.66	1.59
1.97	3.11	23.44	1.88
1.81	2.80	19.78	2.11
1.62	2.58	15.85	2.70
1.51	2.43	13.77	3.06
1.41	2.31	12.01	3.51
1.23	2.27	9.14	5.08

CONCWT=51.0% SGSL=1.135 CONCV=49.2% Cd= 6.314 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.03	5.30	53.72	0.70
2.76	4.78	44.57	0.88
2.41	4.15	33.99	1.21
2.10	3.60	25.80	1.57
1.95	3.37	22.25	1.82
1.80	3.07	18.96	2.03
1.71	2.86	17.11	2.12
1.59	2.67	14.79	2.40

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm FORDING COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MAY 1980

CONCWT=51.0% SGSL=1.135 CONCV=49.2% Cd= 6.314 Temp=17C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.03	5.30	53.72	0.70
2.76	4.78	44.57	0.88
2.41	4.15	33.99	1.21
2.10	3.60	25.80	1.57
1.95	3.37	22.25	1.82
1.80	3.07	18.96	2.03
1.71	2.86	17.11	2.12
1.59	2.67	14.79	2.40

CONCWT=51.0% SGSL=1.136 CONCV=49.2% Cd=17.820 Temp= 7C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.99	5.57	87.84	0.76
2.67	4.54	70.04	0.76
2.39	3.68	56.12	0.73
2.11	2.99	43.74	0.78
1.96	2.56	37.74	0.74
1.81	2.22	32.19	0.73
1.65	1.92	26.75	0.78
1.51	1.70	22.40	0.90
1.39	1.50	18.98	0.96
1.28	1.32	16.10	1.02
1.14	1.06	12.77	1.00

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
SEPTEMBER 1980

CONCWT=18.8% SGSL=1.051 CONCV=15.6% Cd= 5.440 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.02	4.87	40.53	1.59
2.73	4.10	33.12	1.68
2.44	3.45	26.46	1.93
2.12	2.81	19.97	2.38
1.94	2.31	15.05	2.94
1.56	1.95	10.81	4.19
1.60	2.02	11.38	4.09
1.91	2.45	16.21	2.82
1.75	2.18	13.61	3.24
1.49	1.82	9.87	4.33
1.39	1.70	8.59	5.01

CONCWT=30.4% SGSL=1.087 CONCV=26.0% Cd= 5.333 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.10	5.41	42.29	1.26
2.72	4.47	32.56	1.50
2.42	3.82	25.77	1.81
2.08	3.12	19.04	2.23
1.88	2.78	15.55	2.67
1.68	2.51	12.42	3.35
1.55	2.41	10.57	4.14

CONCWT=41.2% SGSL=1.122 CONCV=36.4% Cd= 5.516 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.13	5.77	43.84	1.06
2.79	4.90	34.83	1.24
2.78	4.86	34.58	1.23
2.48	4.17	27.52	1.45
2.16	3.54	20.88	1.83
2.01	3.24	18.08	2.03
1.87	3.00	15.65	2.29
1.69	2.70	12.78	2.70
1.56	2.50	10.89	3.08
1.30	2.17	7.56	4.29
1.15	2.13	5.92	5.97

CONCWT=51.3% SGSL=1.157 CONCV=46.7% Cd= 5.416 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.05	5.82	41.26	1.04
2.69	4.95	32.09	1.25
2.43	4.38	26.19	1.48
2.30	4.10	23.46	1.60
2.12	3.73	19.93	1.81
1.86	3.27	15.34	2.25
1.69	2.94	12.67	2.54
1.57	2.70	10.93	2.78

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm KAISER COAL IN WATER
158.5mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980

CONCWT=53.1% SGSL=1.164 CONCV=48.6% Cd= 4.281 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.96	6.08	34.54	1.23
2.50	4.92	24.64	1.56
2.08	4.02	17.05	2.07
1.72	3.27	11.66	2.68

CONCWT=53.1% SGSL=1.163 CONCV=48.6% Cd=13.484 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.07	6.83	65.95	1.48
2.80	5.35	54.86	1.53
2.46	4.76	42.35	1.64
2.15	3.90	32.35	1.80
1.86	3.16	24.21	2.01
1.57	2.50	17.25	2.32
1.40	2.21	13.72	2.71

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm RAW JUDY CREEK COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980

CONCWT=23.4% SGSL=1.108 CONCV=23.0% Cd= 4.029 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.17	4.76	16.52	4.53
2.96	4.46	14.40	5.07
2.69	4.13	11.90	6.05
2.44	3.87	9.79	7.30
2.21	3.65	8.03	8.80
1.97	3.67	6.39	11.96
1.85	3.53	5.63	13.22
1.79	3.46	5.27	13.93
1.75	3.50	5.09	14.72

CONCWT=36.6% SGSL=1.181 CONCV=38.4% Cd= 4.732 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.26	6.36	18.94	4.15
3.03	5.96	16.36	4.62
2.78	5.60	13.77	5.35
2.54	5.26	11.49	6.21
2.32	5.07	9.59	7.41
2.42	5.15	10.43	6.82
2.26	5.01	9.10	7.78
2.18	5.05	8.47	8.57
2.19	4.62	8.55	7.54
2.20	5.16	8.62	8.63
2.03	4.36	7.34	9.83
1.85	5.34	6.10	13.35
1.83	5.31	5.97	13.58
1.77	5.59	5.58	15.48

CONCWT=48.2% SGSL=1.253 CONCV=53.7% Cd= 3.327 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.31	7.33	16.37	3.55
3.10	7.03	14.36	3.99
2.85	6.64	12.14	4.58
2.68	6.49	10.73	5.18
2.66	6.35	10.57	5.14
2.44	6.26	8.90	6.21
2.44	6.15	8.90	6.07
2.33	6.16	8.11	6.81
2.30	6.30	7.90	7.19
2.29	5.84	7.84	6.60
2.31	6.37	7.97	7.22
2.15	5.79	6.91	7.55
2.18	5.61	7.10	7.02
1.99	6.40	5.86	10.22
1.96	5.94	5.74	9.57
2.03	5.69	6.16	8.40
1.82	6.36	4.95	13.24
1.82	6.63	4.95	12.72
1.68	6.72	4.22	15.24
1.62	6.28	3.92	15.22

CONCWT=59.6% SGSL=1.326 CONCV=69.0% Cd= 3.822 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.24	8.17	16.81	3.45
3.00	7.61	14.42	3.80
2.72	7.09	11.85	4.40
2.44	6.94	9.54	5.54
2.44	6.85	9.54	5.45
2.32	6.82	8.62	6.08
2.34	6.75	8.77	5.89
2.24	6.67	8.04	6.40
2.09	6.64	7.00	7.42
2.08	6.63	6.93	7.48
1.93	6.71	5.97	8.91
1.75	6.69	4.91	10.90
1.59	7.08	4.05	14.10

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
MARCH 1982

CONCWT=33.3% SGSL=1.124 CONCV=27.6% Cd= 3.755 Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.03	5.01	15.26	4.11
2.81	4.74	13.12	4.81
2.44	4.31	9.89	6.37
2.16	3.77	7.75	7.34
1.87	3.72	5.81	10.52
1.78	3.45	5.27	10.73
1.72	3.57	4.92	12.21
1.65	3.47	4.52	12.99
1.50	3.22	3.74	14.79

CONCWT=44.7% SGSL=1.175 CONCV=38.7% Cd= 3.440 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.06	5.28	14.89	3.09
2.90	5.12	13.38	3.49
2.70	4.86	11.59	4.02
2.50	4.48	9.94	4.43
2.37	4.47	8.93	5.15
2.12	4.18	7.15	6.32
1.83	3.90	5.33	8.31
2.01	4.17	6.43	7.22
1.55	3.40	3.82	10.33
1.36	3.33	2.94	13.56

CONCWT=55.1% SGSL=1.224 CONCV=49.8% Cd= 3.814 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.18	5.68	16.94	2.41
2.92	5.28	14.28	2.81
2.77	5.00	12.85	3.02
2.63	4.74	11.59	3.25
2.43	4.54	9.89	3.82
2.31	4.28	8.94	4.04
2.20	4.24	8.11	4.55
2.09	3.91	7.32	4.64
1.91	4.10	6.11	6.23
1.85	3.76	5.73	6.02
1.66	3.61	4.61	7.40
1.41	3.27	3.33	9.53
1.37	3.49	3.14	10.95

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50mm COAL VALLEY COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
ATTRITION RUN, MARCH 1982

CONCWT=55.1% SGSL=1.224 CONCV=49.8% Cd= 3.221 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.11	8.89	14.88	5.20
2.85	7.78	12.50	5.42
2.71	7.49	11.30	5.85
2.66	6.99	10.89	5.57
2.56	6.73	10.09	5.84
2.42	6.42	9.01	6.31
2.30	6.20	8.14	6.82
2.08	5.86	6.66	8.06
1.87	5.81	5.38	10.15
1.80	5.62	4.99	10.60
1.65	5.75	4.19	13.15
1.55	5.41	3.70	14.01
1.34	5.29	2.76	18.47

CONCWT=55.1% SGSL=1.224 CONCV=49.8% Cd= 3.814 Temp=14C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.18	5.68	16.94	2.41
2.92	5.28	14.28	2.81
2.77	5.00	12.85	3.02
2.63	4.74	11.58	3.25
2.43	4.54	9.89	3.82
2.31	4.28	8.94	4.04
2.20	4.24	8.11	4.55
2.09	3.91	7.32	4.64
1.91	4.10	6.11	6.23
1.85	3.76	5.73	6.02
1.66	3.61	4.61	7.40
1.41	3.27	3.33	9.53
1.37	3.49	3.14	10.95

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm FORDING COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
JULY 1980

CONCWT=18.7% SGSL=1.045 CONCV=16.6% Cd= 4.881 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.96	2.91	27.16	2.42
2.71	2.63	22.76	2.95
2.40	2.28	17.85	3.70
2.08	1.95	13.41	4.74
1.85	1.73	10.61	5.84
1.67	1.60	8.64	7.17
1.55	1.52	7.45	8.32

CONCWT=30.2% SGSL=1.075 CONCV=27.6% Cd= 5.309 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.97	3.31	28.52	2.21
2.73	2.99	24.10	2.51
2.38	2.59	18.32	3.21
2.05	2.12	13.53	3.72
1.94	2.05	12.17	4.22

CONCWT=41.1% SGSL=1.106 CONCV=38.6% Cd= 5.172 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
2.95	3.62	27.77	2.00
2.68	3.27	22.92	2.35
2.52	3.11	20.27	2.67
2.29	2.76	16.74	2.87
2.17	2.55	15.03	3.07
1.97	2.32	12.39	3.57
1.85	2.74	10.92	4.34
1.80	2.31	10.34	4.63

CONCWT=51.5% SGSL=1.137 CONCV=49.7% Cd= 5.362 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.22	4.44	33.69	1.71
3.04	4.17	30.03	1.87
2.75	3.75	24.57	2.19
2.45	3.45	19.50	2.75
2.18	2.99	15.44	3.10
1.99	2.67	12.87	3.38
1.83	2.50	10.88	3.86
1.68	2.70	9.17	5.41

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm KAISER COAL IN WATER
263.1mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

CONCWT=18.8% SGSL=1.051 CONCV=15.6% Cd= 6.240 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.21	3.04	29.54	1.69
3.02	2.76	26.15	1.83
2.81	2.45	22.64	1.91
2.57	2.19	18.94	2.37
2.34	1.94	15.70	2.79
2.21	1.82	14.00	3.16
2.07	1.65	12.29	3.40
1.89	1.53	10.24	4.74
1.96	1.53	11.01	3.63
1.85	1.49	9.31	4.44
1.77	1.54	8.98	5.76

CONCWT=30.4% SGSL=1.087 CONCV=26.0% Cd= 5.906 Temp=18C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.35	3.58	31.30	1.45
3.11	3.23	26.98	1.63
2.87	2.90	22.98	1.83
2.66	2.62	19.74	2.06
2.41	2.37	16.20	2.54
2.25	2.22	14.12	2.95
2.06	2.05	11.84	3.52
1.92	1.97	10.28	4.19
1.90	1.90	10.07	4.05
1.82	1.89	9.24	4.64
1.75	1.97	8.54	5.67
1.68	1.80	7.87	5.55

CONCWT=41.2% SGSL=1.122 CONCV=36.4% Cd= 5.611 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.37	3.72	30.88	1.16
3.35	3.68	30.52	1.16
3.11	3.35	26.30	1.33
2.86	3.04	22.24	1.56
2.74	2.88	20.41	1.66
2.52	2.60	17.27	1.90
2.26	2.32	13.89	2.32
2.07	2.17	11.65	2.80
1.94	2.06	10.23	3.18
1.80	2.03	8.81	3.94
1.76	2.12	8.42	4.54
1.69	2.10	7.77	5.02
1.62	2.15	7.14	5.84

CONCWT=51.3% SGSL=1.157 CONCV=46.7% Cd= 5.261 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
3.36	3.98	29.72	1.14
3.12	3.63	25.63	1.29
2.91	3.25	20.79	1.58
2.55	2.93	17.12	1.86
2.28	2.63	13.69	2.27
2.21	2.53	12.86	2.35
2.04	2.34	10.96	2.66
1.88	2.17	9.31	3.04
1.78	2.12	8.34	3.44
1.66	2.08	7.26	4.08

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm RAW JUDY CREEK COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

CONCWT=23.4% SGSL=1.108 CONCV=23.0% Cd= 5.705 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.12	3.50	17.64	4.04
3.94	3.30	16.13	4.26
3.74	3.01	14.53	4.27
3.59	2.85	13.39	4.44
3.47	2.72	12.51	4.61
3.27	2.75	11.11	5.75
3.14	2.68	10.24	6.25
2.99	3.01	9.29	8.66
3.00	2.88	9.35	8.01
2.97	3.15	9.16	9.44

CONCWT=36.6% SGSL=1.181 CONCV=38.4% Cd= 4.564 Temp=20C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.01	4.49	14.95	4.20
4.02	4.65	15.02	4.42
3.90	4.65	14.14	4.82
3.92	4.80	14.28	4.99
4.00	4.86	14.87	4.81
3.37	4.67	13.32	4.95
3.83	4.69	13.64	5.14
3.71	4.25	12.79	4.84
3.61	3.98	12.11	4.72
3.44	3.76	11.00	4.97
3.29	3.53	10.06	5.10
3.17	3.47	9.34	5.50
3.04	3.53	8.59	6.30
2.85	3.43	7.55	7.14
2.69	4.05	6.73	10.19

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm FORDING COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
JULY 1980

CONCWT=18.7% SGSL=1.045 CONCV=16.6% Cd= 4.863 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.23	2.48	29.41	1.83
3.72	2.10	22.74	2.40
3.39	1.82	18.89	2.62
3.17	1.73	16.52	3.31
2.90	1.56	13.82	3.87
2.63	1.34	11.37	4.11
2.37	1.17	9.23	4.74
2.24	1.31	8.25	7.27

CONCWT=29.8% SGSL=1.074 CONCV=27.2% Cd= 6.653 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.15	2.63	33.11	1.63
4.02	2.47	31.07	1.61
3.68	2.23	26.04	1.95
3.29	2.01	20.81	2.54
3.10	1.83	18.48	2.63
2.88	1.57	15.95	2.53
2.58	1.56	12.80	3.87
2.38	1.85	10.89	6.68

CONCWT=33.0%   SGSL=1.096   CONCV=35.4%   Cd= 4.612   Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.18	2.70	27.97	1.33
3.73	2.38	22.27	1.68
3.22	2.04	16.60	2.24
3.16	2.14	15.99	2.68
3.05	1.95	14.89	2.52
2.99	1.87	14.31	2.49
2.85	1.90	13.00	3.07
2.73	1.78	11.93	3.18
2.60	1.43	10.82	2.43
2.40	1.53	9.22	3.69

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm KAISER COAL IN WATER
495.3mm I.D. CLOSED LOOP PIPELINE
AUGUST 1980

CONCWT=18.8% SGSL=1.051 CONCV=15.5% Cd= 5.965 Temp=21C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.19	2.21	26.15	1.25
3.39	2.05	23.71	1.35
3.82	1.90	21.73	1.37
3.69	1.82	20.28	1.53
3.47	1.65	17.93	1.63
3.31	1.54	16.32	1.81
3.22	1.47	15.44	1.84
3.03	1.37	13.67	2.17
2.86	1.30	12.18	2.64
2.40	1.79	8.58	10.02

CONCWT=30.4% SGSL=1.086 CONCV=26.0% Cd= 5.550 Temp=22C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.09	2.23	24.03	1.02
4.01	2.15	23.10	1.01
3.86	2.03	21.41	1.07
3.72	1.92	19.88	1.13
3.49	1.78	17.50	1.36
3.31	1.72	15.74	1.69
3.15	1.66	14.26	2.01
2.94	1.49	12.42	2.11
2.75	1.38	10.87	2.38
2.61	1.36	9.79	2.90
2.52	1.37	9.12	3.40
2.39	1.38	8.21	4.20

CONCWT=43.0%   SGSL=1.128   CONCV=38.2%   Cd= 6.114   Temp=16C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.25	2.52	27.23	0.78
3.76	2.15	21.31	1.02
3.29	1.88	16.32	1.43
3.18	1.75	15.24	1.41
2.97	1.60	13.30	1.55
2.73	1.50	11.24	1.94
2.64	1.49	10.51	2.19

CONCWT=53.6%   SGSL=1.166   CONCV=49.2%   Cd= 5.899   Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.18	2.66	25.97	0.79
3.71	2.34	20.38	1.05
3.21	2.00	15.26	1.41
2.75	1.70	11.20	1.86
2.70	1.66	10.79	1.90
2.61	1.60	10.03	2.00

SASKATCHEWAN RESEARCH COUNCIL
SOLIDS PIPELINE PILOT PLANT DATA

EXCESS HEADLOSS (PHI) vs MODIFIED FROUDE NUMBER (1/KSI)

-50.8mm KAISER COAL IN WATER
495.3mm I.D CLOSED LOOP PIPELINE
ATTRITION RUN, SEPT 1980

CONCWT=53.6% SGSL=1.166 CONCV=49.2% Cd= 6.315 Temp=12C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.18	2.66	26.76	0.79
3.71	2.34	21.08	1.05
3.21	2.00	15.79	1.41
2.75	1.70	11.58	1.86
2.70	1.66	11.17	1.90
2.61	1.60	10.43	2.00

CONCWT=53.6% SGSL=1.165 CONCV=49.1% Cd= 9.630 Temp=19C

VELOCITY m/sec	HEADLOSS m/100m	1/KSI	PHI
4.17	2.44	32.90	0.64
3.74	2.09	26.47	0.77
3.16	1.67	18.89	1.02
2.76	1.42	14.41	1.29
2.41	1.24	10.99	1.71
2.34	1.21	10.36	1.82
2.01	1.09	7.64	2.54

APPENDIX C

SLURRY PIPELINE DESIGN - SAMPLE CALCULATION

A method for designing a coarse coal slurry pipeline is outlined in this section. The method uses the excess pressure gradient vs modified Froude number correlations and the two layer model.

The calculation is based on a throughput of 6×10^6 tonnes per year of coal with the properties of the -50 mm raw Judy Creek coal. The following assumptions were used in the calculation.

1. The coal would have the size distribution of the 36.6% concentration by weight of Judy Creek coal run in the 500 mm pipeline. The saturated coal moisture would be 23.6%.
2. The pipeline would operate 350 days per year.
3. The maximum pressure in the pipeline would be 3400 kPa (500 psi) due to centrifugal pump casing strength limitations.
4. The erosion-corrosion allowance would be 0.127 mm (0.005 inch) per year.
5. The life of the pipeline would be 25 years.

The volumetric flowrate of solids would be

$$6 \times 10^9 \frac{\text{kg}}{\text{year}} \times \frac{1 \text{ year}}{350 \times 24 \times 60 \times 60 \text{ s}} \times \frac{1 \text{ m}^3}{1727 \text{ kg}} = 0.115 \frac{\text{m}^3}{\text{s}}$$

Before the correlations for headloss can be used the limiting velocity has to be established as a function of pipe diameter and solids concentration. The limiting velocities were determined from the following equation

$$V_c = F_L \; [2 \, gD \, (S_s - 1)]^{0.5}$$

Scatter in the experimental data masked any systematic effect of solids concentration. For -50 mm raw Judy Creek coal the average value for F_L was 1.19. To provide a safety margin, the value for F_L was increased by 10% to 1.31. The water saturated solid density was used for the determination of F_L.

$$\rho_s \text{ (saturated)} = \frac{1}{\frac{1-m}{\rho_s} + \frac{m}{\rho_f}}$$

where m = the moisture weight fraction required to saturate the solid. For raw Judy Creek coal,

$$\rho_s \text{ (saturated)} = \frac{1}{\frac{1-0.236}{1.727} + \frac{0.236}{1.0}}$$

$$= 1.474$$

By assuming that the pipe wall thickness will be approximately 6 mm (1/4") the limiting velocities, slurry volumetric flowrates and solids volume fractions may be calculated for various standard pipe diameters.

Pipe I.D.	Limiting Velocity m/s	Volumetric Flowrate (m^3s)	Solids Volume Fraction
343 mm (13.5")	2.34	0.216	0.532
394 mm (15.5")	2.51	0.306	0.376
445 mm (17.5)	2.70	0.419	0.274

It is seldom practical to transport a slurry with a solids volume fraction greater than 0.45. For a 350 mm pipeline, the velocity would have to be increased to 2.77 m/s to reduce the solids volume fraction to 0.45. This would result in high pumping costs. A 400 mm pipeline would probably be selected since the solids concentration would be near 37.6% at the limiting velocity.

The pipeline pressure code (16) would be used to determine the actual pipe wall thickness.

$$\text{Pipe wall thickness, } t = \frac{PD}{2s}$$

where P = maximum internal design pressure, psi

D = outside diameter of pipe

S = maximum allowable design hoop stress in the pipe wall = 0.82 X specified minimum yield strength for pipe diameters less than 20 inches.

If a pipe with a yield strength of 42,000 psi is specified,

$$t = \frac{500 \text{ psi} \times 16 \text{ inches}}{2 \times 0.82 \times 42{,}000 \text{ psi}}$$

$$= 0.116 \text{ inches } (2.95 \text{ mm})$$

An erosion-corrosion allowance of 0.125 inches (0.005 inches per year X 25 years) would increase the required wall thickness to 0.241 inches. Since mill tolerances of 12.5% are permitted the nominal wall thickness would be $\frac{0.241}{1-0.125} = 0.275$ inches.

A pipe with a wall thickness of 0.281" (7.14 mm) would be suitable. The pipeline would have an I.D. of 15.438 inches (392.1 mm).

The next step in the calculation is to establish headloss data as a function of pipe diameter, slurry velocity and concentration. The generalized correlations for headloss are convenient for this. The average drag coefficient for the -50 mm Judy Creek coal is 4.56. For a velocity of 2.50 m/s in a 392 mm I.D. pipeline, $\psi^{-1} = 7.3$. Values for the excess pressure gradient ϕ were obtained from Figures 64, 70 and 73. For the 150 mm pipeline (Figure 64) and the 250 mm pipeline (Figure 70) $\phi = 7.2$ at a solids volume fraction of 0.381 (slurry density = 1.277 g/cm^3). Data were not available for high concentrations in the 500 mm pipeline (Figure 73). However, at a slurry density of 1.181 g/cm^3, $\phi = 7.0$. A value of $\phi = 7.2$ was chosen for the 392 mm pipeline.

At 20°C the predicted headloss would be 0.0495 m water/m of pipe. Since the maximum pressure in the pipeline would be 500 psi (350 m of water) the pump station spacing on level terrain would be

$$\frac{350 \text{ m of water}}{0.0495 \text{ m of water /m}} = 7{,}100 \text{ m}.$$

The generalized correlations were made using in-situ solids volume fractions. For a slurry containing large particles and for velocities near the limiting velocity, the discharge concentration could be considerably less than the in-situ concentration. The two layer model may be used to estimate the discharge concentration. An iterative calculation was made to obtain a velocity and a discharge concentration that would give an annual throughput of 6 X 10^6 tonnes per year with an in-situ solids volume fraction of 0.381. Using $n_s = 0.48$, it was found that the model predicted a discharged solids volume fraction of 0.352, which is considerably lower than the in-situ solids volume fraction. A velocity of 2.7 m/s would be required to deliver 6 X 10^6 tonnes per year. The two layer model predicted a headloss of 0.0505 m of water per m of pipe. Pump station spacing would be 6,900 m on level terrain.

Transportation of the coarse -50 mm Judy Creek coal in slurry form would be practical only for short distances. If long distance transport were considered the particle size would have to be reduced.

APPENDIX D

RESULTS OF COKING QUALITY TEST

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History of Samples for Coking Tests:

Fording Coal (1980)

The Fording coal arrived in Saskatoon on an open truck on February 25, 1980. The coal was frozen when received. Subsequent analysis showed that the coal contained 5.0% moisture. A sample was drummed for later shipment to EM&R in Edmonton. The rest of the coal was dumped outdoors and was covered with polyethylene until it was moved to the storage building at the SRC pilot plant on April 18, 1980. Coal pumping tests were carried out in the 250 mm pipeline during the week on July 7, 1980. The pH of the coal slurries was found to be 6.9. The slurries were pumped for a total of about 4 hours. At the end of the hydraulic tests the coal was withdrawn from the loop through a center stream sampler and placed in drums. In an effort to increase the concentration of solids in the drums, water and entrained fine coal material was allowed to spill over the top of the drums.

The tests in the 500 mm loop were done on July 24, 1980. The running time was about 4 hours. The pH of the slurries was 7.0. Coal slurry samples were withdrawn on July 25, 1980. The sampling procedure was identical to the one used for the 250 mm loop.

Kaiser Coal (1980)

The Kaiser coal was received on August 13, 1980. The coal was stored in an outdoor stockpile. A sample was drummed on August 26, 1980 for shipment to EM&R. A run was performed in the 500 mm pipeline on August 18, 1980. The running time was 12 1/2 hours. The pH of the slurry was 7.4. A sample of the pipelined coal was obtained on August 21, 1980. The sampling procedure was similar to that for the Fording coal.

A run was carried out in the 250 mm line on September 2, 1980. The pumping time was 5 hours. The pH was 7.6. The pipelined coal sample was drummed on September 4, 1980.

Fording Coal - Repeat Test (1982)

An open truck load of coal was obtained from the stockpile of processed coal at Elkford on February 19, 1982. The coal arrived in Saskatoon on February 20, 1982. The coal was frozen on arrival and was stored in a heated garage until February 23, 1982 when the truckload was dumped outdoors at the SRC pilot plant. A sample was drummed immediately for later shipment to EM&R. The coal was run in the 250 mm pipeline on February 24, 1982. The total running time was 65 minutes. The pH of the slurry was 7.4. The total pipeline flow was diverted into a polyethylene lined stockade to obtain a sample. The coal was allowed to settle in the stockade until March 1, 1982. Clear water was removed from the top and the remaining coal-water mixture was drummed. The mixture was shipped to EM&R on March 3, 1982.

Test Conditions:

The following table describes the pipeline loops and other data common to the pumping of both Fording and Kaiser coals:

Pipeline Diameter (mm)	Pipeline Length (m)	Pump Size	Pump RPM (average)	Average Slurry Velocity (m/s)
250	127	12" x 10"	270	2.3
500	137	16" x 16"	350	3.2

The following table gives the number of pump passes for each sample:

Pipeline Diameter (mm)	Passes Through Pump		
	Fording - 1980	Kaiser - 1980	Fording - 1982
250	270	340	62
500	325	1050	--

The following table gives the results of the EM&R coking tests:

Test Conditions:	Coke Stability Factor (cum% + 1 in.)		
	Fording - 1980	Kaiser - 1980	Fording - 1982
Not pipelined	51.2	54.8	51.0
Pipelined in 250 mm loop	45.5	54.0	55.4
Pipelined in 500 mm loop	43.5	50.5	--

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